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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF

IRELAND,

FROM 1870 TO END OF THIRTY-NINTH SESSION, MAY, 1874.

VOL. X.

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TRANSACTIONS

OF THE

INSTITUTION OF CIVIL ENGINEERS

OF IRELAND.

[Read January 12, 1870.]

J. BALL GREENE, President, in the Chair.

On a NOVEL MEANS *of* TRANSIT *for* MINERALS *in the* COUNTY *of* SLIGO. By C. P. COTTON, Member.

DURING the last summer the author had an opportunity of seeing, in full work, a plan for transporting minerals from the top of a mountain direct to the low-lying plain at its foot.

The method adopted was that of hooking on a succession of small boxes to an endless wire rope passing over two pulleys, one at the top of the mountain, the other below in the plain.

As one side of the rope was hung with *loaded* boxes and the other with *empty* ones, the former was continually, when unchecked by the break, descending and the latter ascending.

This adaptation of the wire tramway was quite new to the author, though it was not, as he afterwards learned, an original idea in this instance; but the system, to his knowledge, had never been carried out to such an extent before, the clear distance between the pulleys being in this instance close on half a statute mile.

Apart from the novelty of the plan, and the boldness of the design, this wire tramway of Mr. Barton's is worthy of being recorded among the transactions of the Institution, as it is always useful to have the details of an unique work to refer to, when perhaps the work itself cannot be visited, or may have disappeared *in toto*.

The mineral worked by Mr. Barton is barytes, nearly pure sulphate of baryta, which is found in veins, now and then swelling out into large pockets, in the limestone mountains to the north of the town of Sligo.

Owing to the disposition of the strata the general shape of these hills is very peculiar, the top being generally a flattish table-land, bounded by precipitous sides, as is shown on the section (Plate I., Fig. 1). The barytes is only found on the top of the hill, which in round numbers is one thousand feet above the plain. Here it was formerly worked at various times, but always abandoned on account of the expense of getting it down.

As there is a large pocket of minerals on the very edge of the mountain on Mr. Barton's sett, he began working at this point, and then set about devising some plan of directly conveying the produce down, in lieu of the old system of very small loads on donkeys, which had to travel a long winding and very steep path. His first plan was by means of a long partially flexible wooden tube, 8 inches square in section, made in lengths of 3 feet, each length being slightly inserted into the length *below* it, and the whole connected by two one-half inch wire ropes firmly fastened to each box by staples, and dependent from the upper point of attachment at the edge of the mountain. By this tube the mineral was led to the top of one of the lower precipices, over which it fell, and up the bottom of which a steep winding path was made. The mineral was, of course, greatly scattered in the fall, but as much as could be collected was loaded on small sledges, and horsed down to the public road. Mr. Barton soon found this plan would not answer, owing to the quantity of mineral that was lost at the joints on its passage down the tube, and the small proportion of what fell over the precipice which could be collected.

He then consulted Mr. Hodgson, who is well known as the

introducer of the Wire Tramway System, and the result was the wire tramway which is now at work, and which I shall briefly describe:—

The system consists of an endless wire rope passing round two pulleys, one, above, fixed; the other, below, adjustable.

The upper pulley, whose axle is, of course, normal to the catenary, is furnished with a break. The bearings of the axle of the lower pulley, which is nearly vertical, are capable of being moved horizontally in the direction of the tramway, so as to stretch the rope in the first instance, and afterwards to correct for the lengthening of the rope under work. This correction has come into play to the extent of 4 feet, the rope having stretched 8 feet in a total of 4,760 feet; this Mr. Barton attributes to the exusion of the tar from the core of the rope under the pressure to which it is subjected.

The pulleys are 6 feet in diameter, with a V-shaped groove. The ascending and descending, or the loaded and unloaded, ropes form different catenaries, but the difference of the tangential angles at each end is so slight that the V is sufficient to keep the rope on the pulleys, though the author is of opinion that guide rollers in front of the terminal pulleys would make the whole work more smoothly, and the rope last longer.

The rope is 2 inches in circumference, made of steel wire, and weighs 23 cwt., being 3·25 lbs. per fathom. The horizontal distance between the pulleys is 2,200 feet, and the vertical 1,050 feet. The angle made by the upper end of the loaded rope with the vertical was 37° 30′, and that of the lower end of the same rope was 98°, the angles of the unloaded rope being 38° 30′ and 100° respectively.

The boxes weigh each 11·2 lbs., and carry a load in each of 56 lbs. There are twenty boxes, ten loaded on one rope descending, and ten empty on the other rope ascending. The entire weight borne by the pulleys is thus 30 cwt.

The arrangement is almost self-acting. When a full box

has been hooked on at the upper end the man in charge relieves the break, and the loaded rope moves gently down until the empty box next in rotation approaches the pulley, when the break is put on, the box taken off,* filled, and put on the other rope. At the lower end the rope, which is nearly horizontal, passes over and close to a platform on which a man stands between the wires to take off the loaded boxes as they approach him, empty them through a hole in the platform into a cart, and then hook them on the return rope.

The attachment of the boxes is by a plain wire hook, clasping the rope between two thicknesses of hemp seizing. This gives a good deal of trouble, as it requires constant renewal. It certainly admits of improvement.

The rate of delivery is slow, about one box in each minute, or 30 cwt. per hour.

The fact is worth noting, that even in the middle of this immense span, where looking at them from below, the little boxes appear like infinitesimal balloons, there is *no* inconvenience from vibration of the rope, even with strong winds, nor although the boxes are open are their contents ever spilled.

The erection was a work of some difficulty. The only access to the top, on the side on which Mr. Barton was working, is by a very steep footpath up which all the materials and gear, except the wire rope, had to be carried, and with the large pulley, weighing 6 cwt., the greatest difficulty was experienced. When this pulley was got in place, a light rope was let down and one end of the wire rope attached to it and drawn up, passed round the pulley, and by another rope drawn down, and the two ends spliced. The horizontal adjustment of the lower pulley was made by the weight of water in a box measuring a cubic fathom, which acted by a

* In Mr. Hodgson's Wire Tramway System, as now constructed, a very ingenious arrangement is introduced, by which the box detaches itself from the rope, and runs on wheels *round* the pulley on to the rope again on the other side.

chain passing over a pulley on to the bearings of the axle (Plate I., Fig. 3). By filling this box to a definite height any strain required up to 6 tons can be put on the ropes.

The curves which the ropes assume, it must be remarked, are not true catenaries, and the loaded boxes are at long intervals, and considerable in weight as regards the intervening lengths of rope, and the investigation of the strains does not admit of a complete solution. We know enough, however, to approximate to the working strains.

Assuming that the loaded rope weighs 13 cwt. and its loaded boxes 6 cwt., the total is 19 cwt., and the total of the unloaded rope $11 \times 1 = 12$ cwt.

The angles being as given above.

The tension at upper end of loaded rope is

$$19 \text{ cwt.} \times \frac{\sin. 98^\circ}{\sin. 44^\circ\ 30'} = 28{\cdot}4 \text{ cwt.}$$

The tension at lower end of loaded rope is

$$19 \text{ cwt.} \times \frac{\sin. 37^\circ\ 30'}{\sin. 44^\circ\ 30'} = 16{\cdot}5 \text{ cwt.}$$

This agrees very well with Mr. Barton's observation, that 2 tons of water in the suspended box are always sufficient to stretch the rope, the combined tensions with the friction being probably near this amount.

Though the description of this simple but bold experiment of Mr. Barton's may not be directly of use, as it is unlikely that exactly similar circumstances will again be found combined, yet the knowledge of what *has been done*, of the immense space and height which *have* been successfully dealt with, and the fact that it was not merely theoretically possible but practically a success, may encourage to still bolder designs engineers who may encounter difficulties similar to those so successfully dealt with by Mr. Barton.

[March 9th, 1870.]

C. P. COTTON, Hon. Sec., in the Chair.

On PERMANENT WAY.

By CHARLES G. NAPIER, Member.

IN the following notes on Permanent Way, the author begs to disclaim any pretension to novelty or originality. They are simply the result of observations made from time to time in the course of some years' professional experience, and, as such, are offered for discussion and criticism at this Meeting.

It is unnecessary to dwell on the importance of the subject. To convince one of this, a very slight consideration of the forces brought into play in a travelling train must be sufficient. The train weighs, perhaps, 100 tons, the engine 35 tons more. The whole of this mass, with its load of human beings, is whirled along at a speed of 40 or 50 miles an hour, and when we consider the momentum it must acquire; that its only safe position is while its wheels run along rails not three inches wide; and that the only means of keeping them there is by flanges but an inch and a quarter deep; when we consider all this we may well be led to wonder at the scarcity of accidents, rather than at their frequency—and thence, to speculate on the conditions of safe railway travelling—how to ascertain, and how to define them. In pursuing these reflections, the mind seems invariably to be forced to an uneasy conviction of the scantiness of our knowledge on the subject, and of the difficulty of making observations likely to be of practical value.

Speaking, generally, there are two systems of Permanent

Way in use in Ireland; with one the rails are laid on continuous bearers of timber, tied together at convenient distances to preserve the gauge; with the other the rails are laid on a succession of cross sleepers about a yard apart.

The continuous bearing afforded to the rails by the first, besides admitting of the use of a lighter rail, undoubtedly assists in absorbing the vibration and concussion generated by trains travelling at speed, and thus diminishes the wear and tear; but it is difficult of repair, and there is also a scarcity of ties to counteract the tendency which the flanges of the wheels have to force the rails apart or to spread them; with cross sleepers, on the contrary, there is great facility in carrying out the repairs and renewal, and the number of ties which they form, add much to the security of the road, especially in case of accident, or if the materials happen to be old. As the cross sleepers, however, give, not a continuous, but an interrupted bearing, the rail must be of sufficient strength to carry the passing load over the space intervening between the sleepers.

Notwithstanding some theoretical advantages in the longitudinal bearer, the general result of experience seems to indicate that the balance of advantages is in favour of the cross sleepers—that, in this way, it is easier to secure the proper maintenance of an efficient Permanent Way; and in all engineering works practical efficiency must content us, because we shall always fall short, not only of theoretical perfection, but even of that approach to it, which, under very favourable circumstances, may be obtained. Thus, a mile of rails on longitudinal bearers may be laid down and, perhaps, by extreme attention, may be kept in a condition superior to anything which can be reached with cross sleepers; but it will be at a cost which renders it practically unattainable on a large scale.

Of the form or section of rail in general use there are three—

1st. The Double-headed Rail.
2nd. The Vignolles or Flanged Rail.
3rd. The Bridge Rail.

The first is generally laid in cast-iron chairs attached to the cross sleepers by spikes or bolts. The rail being secured in the jaws of the chair by keys of hard wood.

With the flanged rail the cast-iron chair can be dispensed with, and the rail itself bolted or spiked directly on to the sleepers.

The double-headed rail undoubtedly possesses many advantages. Among the first of which is to be reckoned the broad bearing on the sleepers, which is obtained by the intervention of the chair—this, by distributing the weight over a greater surface of timber, saves it from crushing—and, as long as the rail is secure in the chair, gives greater stability to the road. It has always appeared to the author, however, that the ordinary method of securing the rail in the chair is defective and requires improvement. The chairs and keys add nearly 20 per cent. to the first cost in materials, as compared with the flanged rail.

The third section of rail is the Bridge Rail. This has been laid both in cross sleepers and longitudinal bearers. Among the advantages it possesses, are—1st. The comparative breadth of base and consequent stability; 2nd. The breadth of the face of the rail; and 3rd. The strength and capacity of wear in the head of the rail.

As a practical illustration of this capacity for wear, there are here two pieces of rail, both (as far as we have been able to ascertain) originally of the same section, but one of them worn down nearly one inch. It is noticeable that of these two pieces of rail, that which is least worn down appears to have been longest in use. It comes from a portion of the G. S. & W. Railway, between Charleville and the Limerick Junction, while the other piece comes from the down line in

the Tunnel at Cork. It is obvious that neither of the other two sections (Plate II., Figs. 1 to 10), would admit of anything like the wear which Fig. 5 and the specimen exhibit; but against these advantages in the bridge-rail there is this disadvantage—it does not admit of the fished joint which is so easily adapted to Figs. 1 and 2. Harty's chair has been extensively used with the bridge-rail, as apparently making the best joint yet contrived, and applicable to that section. It is sufficiently strong and superior in security, although somewhat inferior in smoothness to the fished joint.

Whatever section of rail be used, there can be no doubt of the very great importance of securing a broad face to the rail, and of the advantage of making the form of the head correspond with that of the tyre of the wheel. To illustrate this, Fig. 8 shows the section of a rail actually in use in this country, and over it is shown the section of a tyre of a wheel also in use. In Fig. 7 is shown the same tyre placed over an imaginary section of rail made to suit it. No one, we will venture to say, looking at these two figures, can for a moment doubt that the wear and tear of the wheels in Fig. 8 would greatly exceed that which, *cæteris paribus*, would take place if they ran on a rail having a head such as is shown in Fig. 7. In the first case the wheel would wear as in Fig. 10. In the second they would wear evenly, and consequently last much longer. Suppose, however, that by great attention and expense the wheels used with the rail shown in Figs. 8 and 10 were kept true; there is another objection to the light rail, namely, that the oscillation from side to side would be more rapid, and any slight inequality in the surface of the rail more easily felt than with the broad rail; this rapid oscillation is very objectionable.

It must not, however, be supposed that even with such a section as is shown in Fig. 7, the wear of the rail and wheel would exactly correspond; although the wear of both would

be more even than with the narrow rail, the tendency would still be to flatten the rail, the section of which, as it approached more nearly to that shown in Fig. 5, would become more and more destructive to the wheel.

The great superiority in principle of the fish-joint over any other yet designed, is so well established as to require no remark; but there is another form of joint which has been extensively used with the bridge-rail in this country, and which appears so objectionable as to deserve a few remarks on its defects.

With this joint the ends of the rails meet on a wrought-iron chair having a vertical rib to fit the hollow of the rail; this chair, which is the same width as the base of the rail, rests on a broad sleeper—two fang-bolts passing through both rail and chair, fasten the end of each rail to this sleeper. (See Plate II., Fig. 11). Now, in the first place, the effect of the passing load on so short a joint as this, is that the end of the chair becomes a fulcrum at A, and if there is any yielding of rail or sleeper at B, the rail becomes a powerful lever on the fang-bolts, causing them to start and get loosened, to the destruction not only of the smoothness and tightness of the joint, but also of the timber; for the bolt holes, from the continual working of the bolts, become enlarged and admit wet, which soon leads to the decay of the sleeper; but there is another effect which the passing load exercises on this joint. In a double line, where the traffic is always passing in one direction, there is a tendency in the passing load to push the rail along in the same direction. The effect of this tendency is seen on spikes and bolts which have been in use for some time; the side of the bolt opposed to the traffic being worn by the pressure of the flange of the rail against it. It would be satisfactory to have the accuracy of this observation corroborated by other evidence. These effects have so repeatedly come under the observation of the author as

to leave him no room to doubt that this action goes on; neither does there appear to be any primâ facie improbability in the matter. In the joint with which we are now dealing, there is a tendency in the joint sleeper to become tilted or canted over in the direction of the passing load; the cause of this appears to be the pressure of the rail in its forward movement on the bolt, and the effect is to cock up the end of the rail and thus lead to its fracture at C.

Mr. Harty uses a longer chair and rests its ends on sleepers about 18 inches apart, to which he attaches both rail and chair by fang-bolts—this lengthening of the joint, so that it has a bearing of 3 feet instead of one—greatly relieves the strain on the fang-bolts, and practically gets rid of the tendency in the sleepers to become canted. This joint when properly fastened and attended to, is little inferior to the fish joint in smoothness, and is superior to it in security; because with the fish joint any malicious person with a spanner can unscrew the nuts and remove the fish-plates, thus breaking the road. Whereas with Harty's joint it is necessary to take out the fang-bolts, which attach both rail and chair to the sleeper, and also to lift the rail before the joint chair can be removed.

We have, both in this country and in England, generally adhered to the use of timber as a support for the rails. There have been many ingenious designs for adopting some material of greater durability, but it is doubtful whether any will be found so capable as timber of absorbing the great vibration and concussion, which must always be generated by the passage of heavy trains at high speed. It demands both care and judgment in the selection. It appears to the author that, when properly selected, the native larch is fully equal, if not superior, to any foreign timber offered for sale for sleepers in this country; and, in small quantities, it can be obtained at a cheaper rate. The Scotch fir grown here, when it has been allowed to attain maturity under favourable

circumstances, makes excellent sleepers. When felled before it has attained maturity, it is full of sap, and comparatively worthless. It is to be regretted that landowners in Ireland have not bestowed more care and attention on the growth of timber for useful purposes; there is a considerable proportion of land in Ireland extremely well-fitted for the growth of larch and Scotch fir, and of inferior value for other purposes. And home-grown timber has one marked advantage over foreign, namely, that the soil and situation in which it is grown, the time at which it is felled, and the subsequent treatment which it receives are easy to ascertain. On these circumstances the value of all timber must in a great measure depend.

Nothing hastens the decay of sleepers so much as the boring of holes in them for the reception of the fastenings. If some simple means could be contrived for securing the rail to the sleeper without boring holes in the latter, or even of excluding the wet perfectly from the holes, the durability of a sleeper would be considerably increased. It has been suggested to the author by a naval officer, that if the holes in the sleepers were filled with hot tar before driving the spikes or bolts this object might be attained. The remedy is so simple as to be worth a trial.

The author has made some efforts to arrive at a satisfactory conclusion as to what may be taken as the average life of a sleeper, but the data from which the calculation should be made are difficult to collect and determine. The original quality of the sleeper ought to be known; for those of a superior quality, favourably placed, will last as much as twenty years; whereas inferior sleepers, such as are now frequently purchased by Railway Companies—on account, we will not say of their cheapness, but of their low price—will decay in three or four years. There are, besides, many other circumstances, such as the amount and nature of the traffic running over them, the

speed of the trains, the description and weight of the rail, which must all be taken into consideration in determining when a sleeper has become unfit to be retained in a line. Moreover, if the removal of the sleepers on a railway has for a few years been neglected, or carried on in too niggardly a way, the lost ground would of course have to be made up by exceptional renewals; and an average life of a sleeper, calculated from a line undergoing such renewal, must necessarily turn out very fallacious.

Without pretending to mathematical accuracy, however, we may estimate that, under ordinary circumstances, in this country fifteen years may be taken as a fair average life for a sleeper; or, in other words, that if Irish Railway Companies were steadily to renew one sleeper out of every fifteen in each year, their permanent way would be sufficiently maintained in this respect. Of course, however, if, say for two years, only half the quantity or one sleeper in thirty is renewed, the supply for the third year must be double the calculated average. This may appear so simple as not to require statement, but it is surprising how completely these simple calculations are sometimes overlooked; and this seems no inappropriate time or place to allude to matters which so seriously affect that part of railway economy coming immediately under the supervision of civil engineers. From various causes, it is not always possible for engineers to carry out their works as they would themselves desire; but when it is possible it certainly appears preferable to have sleepers uniform in size, age, and quality, and to have them renewed, where they require renewal, en masse. This wholesale renewal would insure a more uniform and regular degree of yielding under the passage of trains. After they have been carefully packed and attended to, and then for some time left undisturbed, the ballast under them becomes consolidated and concreted; but if only one out of every four or five sleepers be renewed, the

new sleeper will require some little time and repeated packing before it can have acquired as solid a bed as the older sleepers, and till it has done so there must be a greater yielding under the passing load there than elsewhere, thus causing a local deflection of the rail and impairing the smoothness of the travelling.

If, on the other hand, all the sleepers were renewed at once, although for a time there would be considerable yielding, it would be more uniform, and consequently the train would run more smoothly.

Good drainage, and therefore good ballast, assists powerfully in preserving the sleepers. Generally speaking, the eskers or gravel ridges, which form so remarkable a feature in the geology of Ireland, yield excellent ballast, being composed of pebbles of limestone and of the harder rocks. In the old red sandstone districts the ballast is not so good, the pebbles being more liable to disintegrate by exposure to weather, and the permanent way is consequently more costly of maintenance.

No attempt is here made to estimate the life of a rail; its duration depends, no doubt, on the tonnage and speed of the trains passing over it, but it also depends on the section of the rail, the description of the joint in use, the quality of the iron or steel, and on the manner in which the line is maintained. Rails cannot be expected to last well unless the renewal of the sleepers on which they are bedded is attended to, and the bedding of the sleepers themselves is kept good and even by proper packing and efficient drainage. Any estimate which, omitting these important considerations, is based solely on the speed and tonnage of trains fails to include all the elements required to insure an accurate result.

The question continually forced upon the consideration of a permanent way engineer is this—Wherein does the safety of trains travelling at speed consist?

The author is most anxious, in any remarks which he may offer, not only to state with accuracy any ascertained knowledge, but also to admit with candour the amount we have yet to learn.

The most usual practical demonstration which we have of danger is the actual occurrence of an accident, and then the result is frequently death and injury to travellers—at best destruction of property and expense to the Company.

As has been before said, the conditions of safety are imperfectly known; the accident leaves everything disturbed; carriages and waggons, and perhaps engines, broken, and permanent way torn up; and it is fortunate if nothing more has to be added to the list. Those who have usually the earliest opportunity of looking into the immediate cause of the accident are persons in the lower classes employed by the Company; they know the difficulty of judging of the real causes of accidents, and the facility with which blame is fastened on individuals; consequently it must frequently happen that the first effort of these people is carefully to obliterate every vestige of evidence which may possibly inculpate them as having contributed to the disaster.

Nor is this to be wondered at when we consider the great public excitement which any serious railway accident causes—the results are so lamentable, and the dangers attending all travelling are so concentrated on these occasions, that the public mind is often, we might say, rabid for a scapegoat, and some ordinary official, who has been guilty of a culpable, but not extraordinary, piece of carelessness, is made to suffer as if he alone were responsible for every life lost. This is not just, and it will not improve railway management, because it practically results in the punishment of faults *only where they produce active mischief.* The object with railway companies should be—1st. To ascertain and classify the proximate causes of accidents, and then to establish so strict a discipline

as to insure, as far as possible, that any neglect on those points which lead to accidents, shall be equally punished, *whether any evil consequence has resulted from the neglect or not.*

Some of the conditions of safe railway travelling must obviously depend on the mutual relations between the rolling stock and permanent way. That is—

1st. The gauge of the wheels and rails must correspond.

2nd. The surface of the rails must be maintained uniform and free from depressions and unsoundness; and equally with the rails, the tyres of the wheels must be kept free from uneven wear and defects.

3rd. On curves the super-elevation of the outer rail must be sufficient and uniform, and the carriage must be adapted to run with facility round them.

It has sometimes been thought advisable to lay rails rather wide to gauge in the first instance, but the benefit of this may be doubted, because the inevitable effect of the traffic is to spread the rails, and therefore it is better to have them exact to gauge at first. There is not, however, so much risk as is sometimes imagined in having rails considerably wide to gauge. It may be seen by the figure (Plate III., Fig. 1), that with correct and unworn tyres the gauge might be as much as $2\frac{1}{4}$ inches wide without risk of the wheel dropping inside.

In Fig. 2 the six wheels of a carriage are shown on a sharp curve. It will be seen by this, that while the outer flange of the central pair of wheels is away from the rail, the flange of the leading wheel No. 6 will be grinding against the rail, if the axle boxes fit so tightly in the axle guards as to keep the wheels in a straight line (as shown in the figure). If, however, there is some play allowed, the wheels accommodate themselves to the curve in the manner shown in Fig. 3, and the grinding of the leading flange on a sharp curve is diminished, and with it the risk of a carriage

running off the line. Observe, however, that in the diagrams the scale is exaggerated, in order more plainly to illustrate the mechanical action which takes place. The curvature, even on sharp curves, is really very slight for the ordinary wheel base of a carriage; but, nevertheless, the action which we have endeavoured to explain is not without its effects, and must not be overlooked. How far this play in the bearings of carriages and engines may be desirable in other respects is a question for mechanical engineers; but an inspection of the diagram will, as it seems to us, at once show the practical advantage that must result from a good system of radiating the axles to the centres of curves.

A good many years ago the author had an opportunity of seeing this carried out, as it appeared, very successfully on the Paris and Sceaux Railway. He has not since seen or heard anything of the line, but it is rather a matter of surprise that the ingenuity there shown has not some more practical fruit.

There is another matter so closely connected with permanent way that it ought not to be passed over unnoticed—that is, the tendency in running round curves for the axles of wheels to become twisted. The outer wheel running round the outer rail of a curve, and having consequently to travel over a longer distance, would, if rotating freely on its axle, perform a greater number of revolutions than the inner wheel, but both wheels are keyed on the axle, and they cannot, therefore, rotate freely and independent of each other, and thus two sets of rotating forces are generated in the wheels, acting in the same direction indeed, but unequal, and their resultant is torsion of the axle.

It is evident that if the wheels were capable of revolving on their axles independent of each other, so that the outer wheel were free to perform as many more revolutions as the additional length of rail which it had to traverse required, the

risk of twisting and consequent fracture of axle would disappear. This also is a question for mechanical engineers, but the fracture of axles is so frequent that it assumes great importance.

The amount of super-elevation to be given to the outer rail in curves, also requires careful consideration. Simple formulæ have been devised for calculating what this should be, but no formulæ can meet all the circumstances which arise in practice, because a rule which is correct for trains travelling fifty miles an hour is incorrect for trains travelling only twenty.

It appears, indeed, that accidents arising from trains running off at curves are not frequent, and the author is disposed to think that an excess of super-elevation in sharp curves is more likely to lead to accidents than a deficiency. To explain:—take, for instance, the four wheels of a carriage on a sharp curve, as represented in Fig. 4. If the rails are of even height and the carriage at rest, the weight with which each of the wheels bears on the rail will be the same. If, however, the outer rail is elevated, the weight is thrown more on the inner wheels, 1 and 3.

If the super-elevation of the outer rail is correct for a speed of fifty miles an hour, then the vertical pressure would be again the same on all four wheels when the carriage travels at that speed. As before observed, there is a tendency in the flange of the outer leading wheel, No. 4, to grind against the rail, and the force counteracting its consequent tendency to mount the rail is the pressure upon it. But if—the super-elevation being for fifty miles an hour—the actual speed is only twenty, then the pressure on the outer wheels is diminished, and that on the inner wheels increased, and the tendency of the outer leading wheel No. 4 to mount the rail and run off, has less to control it.

And if besides this, from an ill-packed sleeper, a worn rail,

a defective tire, or any other cause, a further and sudden depression happens to occur at the inner trailing wheel, additional pressure must be thrown on it, and taken off the outer leading wheel, thereby further increasing the risk of its mounting the rail.

For these reasons, I am disposed to think that the super-elevation of the outer rail in curves ought to be for something below the average speed.

It may not be out of place here to give a short account of an accident which occurred to a goods train, and came under the immediate observation of the author (Plate IV).

The general result of the accident was that, out of a train consisting of twenty-six waggons and two vans, sixteen waggons, as shown in the figure, got off the rails. After the line had been cleared, a careful examination of the indications of the accident was made. The results were, briefly, as follows:—

There were marks of one or more pair of wheels being off the line for over two and a-half miles from the place where the train ultimately broke down; but the first indication of a waggon having been off was extremely slight, there being only the mark of one flange, and that very light, indeed, on the sleepers close to and inside of the right hand rail. This light mark of the right hand wheel continued in the same position for about three quarters of a mile, when it suddenly got heavy—its position was altered—and marks of the left hand wheel also appeared (for the first time) outside the left hand rail (see Fig. 1). After this the marks continued heavy, and there was evidence of more waggons having got off to where the train ultimately broke down.

It appeared very remarkable that for the first three quarters of a mile the left hand flange should have left no mark whatever, so careful measurements were made, from the mark of the right flange, to ascertain where the other would be,

suppose the wheels were correct to gauge, which they were found to be after the accident. These measurements showed that the left hand flange would come on the top of the left hand rail (see Fig. 2); but this made the matter still more difficult to explain, because it appeared almost incredible, supposing the buffers of the waggons to be free, and the train connected and drawn along by the coupling chains, that this left hand flange could have maintained its position on the top of a narrow rail for three quarters of a mile. Besides this, why were the marks of the other flange so light as in some cases scarcely to have marked the sleeper? It was necessary to look farther for an explanation, and that which appears the true one is as follows:—The section (see Fig. 3) shows the gradients at the place where the first mark occurs; the line curves to the right. There is drawn on the section that which, according to conjecture, must have been the position of the train at the time the first derangement occurred.

The sixteen waggons which ultimately all got off the line are cross-hatched in the Plate.

In the hinder part of the train the waggons were heavily laden with sacks of flour and corn. Most of the waggons in the front part of the train were also heavily laden; but there were in the centre two or three lightly-laden waggons mixed with heavy ones.

There would, therefore, be an irregularity in the height of the buffers, those belonging to the heavy waggons being lower than those belonging to the light waggons. This irregularity would be increased if the heavy waggons were old and the light ones new.

The conclusion arrived at is, therefore, as follows:—The train being in the position shown in the drawing, the speed of the engine and forward part of the train had become somewhat checked by the ascending gradient, while the hinder part of the train, with its heavy load, was still in full swing

down the descending gradient; this caused a sudden closing up and squeezing of the buffers—it might almost be described as a collision in the train itself; and in the course of this the front buffers of a heavy waggon got under and lifted the left hand hind buffer of a light waggon in front of it, which thus got jammed in that position (see Fig. 4); the whole weight of the body of the light waggon was thus borne by the heavy waggon, and the left hand trailing wheel mounted the rail (being pushed on to it from behind), and there hung in the axle guard, just touching the rail. The right hand trailing wheel dropped inside the rail and left the light marks which were seen—light because the wheel was relieved from the weight of the waggon. In this position the train went along up the incline and for three quarters of a mile until the buffers, from some cause, got free of each other, when the body of the waggon dropped on the wheels; the left hand wheel at once slipped off the rail and the marks thenceforth became of course strong; after this more waggons got off, till eventually the train broke down.

The deductions the author draws from what is above described are:—1st. That when two descending gradients meet, it is necessary to have a sufficient length of horizontal rail for the train to steady itself after its descent and before beginning its ascent; and

2nd. That the mixture of light with heavy waggons in a long goods train is objectionable on account of the inequality which it causes in the height of the buffers.

On the following page is a record, in a tabular form, of the cost of maintenance, during the last four years, of some lines under the author's supervision. They have been put in the form now required by Act of Parliament, but condensed; and although four years is far too short a period to get fair averages, the record will possess some value; and if others who have the opportunity would contribute similar information,

—	Age, Dec., 1869	Length in Miles	Maintenance and Renewal of Way										Bridges and Works, Signals, Stations, &c.					Total Cost per Mile				
			Salaries and Wages					Materials														
			1866	1867	1868	1869	Average	1866	1867	1868	1869	Average	1866	1867	1868	1869	Average	1866	1867	1868	1869	Average
	Yrs. Mos.																					
A Double,	20 6	57·5	62·2	80·3	80·8	93·9	79 3	114·1	127·8	83·2	137.5	115·6	34·6	25·8	37	36·3	33·4	210·9	233·9	201·0	267·7	213·4
B Single,	16·8	40	32·9	39·5	46·8	39·7	39·7	35·5	14·4	39·4	46·5	33·9	6 9	10·4	10·8	5	8·3	75·3	64·3	97	91·2	81·9
C Single,	10·6	22	28·1	31·5	35	42·7	34·3	5·2	14·5	14·1	26·1	15	7	8·1	6	4·7	6·4	40·3	54·1	55·1	73·5	55·7
D Single,	9·8	16·75	—	23·3	27·9	30·9	27·4	—	15·8	16·8	41·5	18.5	—	9·5	7·4	12·6	9·8	—	48·6	52·1	85	1·9

in a few years some valuable statistics might be collected through the instrumentality of this Institution.

Before bringing these notes on Permanent Way to a conclusion, there is another matter which requires some special observation—the management of men. Wages form so large an item in the general expenditure of all railways that, even in a pecuniary point of view, the subject is of high importance. When workmen are collected together in one place, or within a short distance of each other, careful supervision and management is comparatively easy, but when, as in railways, they are scattered over a length of hundreds of miles, it becomes impossible for an engineer to exercise the amount of personal superintendence which would be desirable; and there are many causes in railway work which tend to make men careless and indifferent; there is often a degree of monotony scarcely suited to the temperament of Irish workmen, and sometimes such an absence of fair promotion and advancement, that men of good abilities and industry become careless from want of stimulus, and carelessness is the prolific mother of accidents.

The duties required by all railway officials might, perhaps, be more efficiently performed if a system of discipline analogous to that which exists in the army and navy were introduced. It is not usual for civilians, accustomed as they are to look to the action of civil laws and to motives of self-interest for the regulation of the conduct of men, to attach meaning to the word discipline, which, nevertheless, when rightly understood and practised, constitutes a great moral force. It is, in fact, the means by which bodies of men can be made to act in unison for a common object, leading them to consider as virtuous, conduct which conduces to the attainment of that common object, and as criminal that which militates against the attainment of it; and thus it becomes a sort of bastard religion, and creates a special class of

virtues for a special object—with armies for purposes of war, with navies for the management of ships; but there is no reason why other bodies of men should not be subjected to a discipline suited to their occupations; and it seems probable that a better study of this science of discipline in connexion with persons employed on railways might insure a more efficient discharge of their ordinary duties, and greater safety in the working of trains. In conclusion, the author apologises for the desultory and imperfect nature of his paper. He claims for it no originality nor scientific pretension; but, in obedience to the custom of this Institution, he has endeavoured to lay before the meeting some few of the many topics of interest connected with "Permanent Way," in the hope that those who are better qualified will correct his remarks where they are in error, and improve on them should they possess any value.

[May 10, 1871.]

ROBERT MANNING, Member of Council,
In the Chair.

On a 50-TON MASTING SHEERS. By JOHN BAILEY, Member.

THE "Masting Sheers," the construction of which is now laid before this Institution, have just been erected, for the Belfast Harbour Commissioners. alongside the "Abercorn Basin," in that port, by the firm of Courtney, Stephens, and Bailey, of this city. They consist of *one* diagonal and *two* upright hollow boiler plate legs or struts, or in other words, two front legs and one back (Plates V., VI., VII.). The front legs are each 105 feet 6 inches in height from centre to centre of pins, 32 inches in diameter in the centre, tapering to 16 inches at the ends. The thickness of the centre plates for a length of 60 feet is $\frac{3}{8}$-inch, and the remaining plates at either end $\frac{7}{16}$-inch. They are butt-jointed endways, with external and internal cover straps; the external being 7 inches by $\frac{1}{2}$-inch, and the internal 7 inches by $\frac{1}{4}$-inch (Fig. 3). The vertical joints are lapped, and single rivetted with $\frac{3}{4}$-inch rivets. Massive cast-iron shoes and caps (Fig. 3) are loosely fitted to the top and bottom of each leg, care being taken that they butt well home. Four wrought-iron keys are then fitted and driven between each casting and the legs, the intermediate space being fitted with iron borings or hard wood packings. Through the cap castings is passed a wrought-iron pin $6\frac{1}{2}$ inches in diameter at the centre, and 6 inches at each end, fixed by means of cotters and washers.

The shoe castings work between heavy-jawed baseplates,

on a 4-inch wrought-iron pin. The back leg is 132 feet 2 inches in length by 3 feet in diameter in the centre, by $\frac{5}{16}$-inch in thickness, and 18 inches at the ends by $\frac{3}{8}$-inch in thickness.

The transverse outside butt strips are 12 inches by $\frac{5}{8}$-inch, and the inside ones 12 inches by $\frac{1}{4}$-inch. To each end of this leg is rivetted suitable strap forgings (Fig. 3), having two wrought-iron hoops 9 inches by $\frac{1}{2}$-inch shrunk over all; through the upper forging is passed the pin that secures the front legs together, and the lower one (Fig. 4) takes hold of a forged crosshead, through which passes a wrought-iron square-cut screw 41 feet 6 inches in length by $6\frac{1}{2}$ inches in diameter by $1\frac{3}{4}$ pitch, supported in the centre by a cast-iron rocking bearing; this screw has seven thrust collars at the end, and works in a large cast-iron bed, held down to the masonry foundation by twenty-six 2-inch holding-down bolts. Wrought-iron slabs or caps are fitted and secured to the top part of this bedplate by the holding-down bolts and intermediate ones attached to the flange of the casting only; these bolts are placed closer together, being only 8 inches asunder, on approaching the outer end, as the strain, of course, is greatest there, or entirely on them; whereas they are relieved of all, except a slight sheering strain, when the legs are run in; the bolts are therefore 2 feet 4 inches asunder at this end, a brass nut 12 inches in length by $\frac{3}{4}$ of an inch in thickness working directly along the main screw. Each end of this crosshead has a trunnion turned upon it (Fig 4), and on these trunnions and outside the strap forgings are two cast-iron sliding blocks, run with white-metal in dovetail grooves; the bottom of these blocks rub on a projection of the cast-iron bedplate. The screw is actuated by means of a pair of spur wheels 2·3 to 1. The pinion, which is keyed directly to the engine shaft, is 11 inches in diameter by 5 inches wide, by $2\frac{1}{4}$-inch pitch, and has sixteen teeth. The wheel, which is keyed on

to the end of the screw, is 34·4 inches in diameter by 5 inches on face by $2\frac{1}{4}$ inches pitch, having forty-eight teeth. When the screw revolves, the back leg travels either backward or forward along its entire length at the rate of 13 feet per minute, thus altering the angle (75° when run out) of the sheers. This screw is actuated by a pair of horizontal direct-acting, high-pressure engines of 18 H.P. collectively, having cylinders 12 inches in diameter by 15 inches stroke, the pistons running at about 200 revolutions per minute, and fitted with link motion, moved by a spring-catch reversing lever. The boiler is of the ordinary Cornish type, 5 feet 3 inches in diameter by 17 feet 6 inches in length, with a centre flue 2 feet 6 inches in diameter the entire length; it has outside angle irons and three gusset stays at each end, and $1\frac{1}{8}$-inch through stay.

The winch or hoisting barrel (Fig. 5) is placed immediately in front of the bedplate, and is 3 feet in diameter by 7 feet $3\frac{1}{2}$ inches in length, with a spiral groove cast in to suit the chain; its weight is 4 tons 3 cwt. A wrought-iron shaft, 3 inches in diameter by 10 feet 6 inches in length, swelled to 5 inches and $3\frac{7}{8}$ inches at the ends, is passed through and firmly keyed to same, supported by two cast-iron brackets firmly bolted to the foundations by five 2-inch bolts in each. To one of these brackets is attached a small casting, forming a bath of oil, with a wrought-iron worm revolving in it (Fig. 6) by means of a line of 3-inch shafting running alongside the bedplate, and attached to the engine shaft by a clutch coupling; the diameter of this worm is $8\frac{1}{4}$ inches by 3 inches pitch, single threaded, which acts upon a tangent wheel 4 feet 4 inches in diameter, fitted and bolted to one flange of the chain barrel.

The hoisting chain is 748 feet in length, of the best best short link, $1\frac{1}{8}$-inch in diameter; the upper or fixed block, which is supported from the centre pin, contains four sheaves,

each 2 feet by $4\frac{3}{4}$ inches. *Three* of these sheaves are used for heavy lifts, with five falls of chain; the remaining one is used for lighter lifts, with a separate running block and only two falls of chain 376 feet in length.

The erecting, which is at all times rather a dangerous operation, was carried out thus:—The three legs were laid flat on the ground over the site they were to occupy, and the bottom shoes (AA, Fig. 7) fixed to their bedplates; the ends of the front legs were then slipped loosely into the bottom shoes. A pair of monkey sheers, about 50 feet in height, were then erected between the caps of the front legs and the main surging barrel. On these were rigged a set of 25-ton blocks, taking a 7-inch rope, the bight of which was passed along to the 10-ton crab winch, W. By this means the sheers were lifted bodily to the height of about 45 feet. We then connected a double set of 8-ton purchase blocks to the far end of the back leg, one set on either side, using 5-inch ropes in preference to chains, the falls of which were carried to the 5-ton crab winches, CC.

To prevent the thrust on the quay walls at the points AA, a chain was passed round the bedplates and the hoisting blocks attached to it, thus tying all the three legs together. A timber slide or slipper, well greased, was fixed for the back leg to travel along. The author is happy to say all went smoothly after the monkey sheers were removed, and the time occupied in hoisting was about eight hours.

[December 13, 1871.]

BINDON B. STONEY, President,
In the Chair.

On the APPLICATION *of* PORTLAND CEMENT *to* MARINE WORKS. By the PRESIDENT.

OF the various inventions which have been made in the arts of Construction within the last half century, there are few that can compete in importance or extensive application with Portland cement, so named from its resemblance to the well known Portland stone. For this invention we are indebted to a bricklayer of Leeds, in Yorkshire, named Joseph Aspdin, who took out a patent for artificial stone on the 21st of October, 1824, which he thus describes:—

"My method of making a cement or artificial stone, for stuccoing buildings, waterworks, cisterns, or other purpose to which it may be applicable (and which I call Portland cement) is as follows: I take a specific quantity of limestone, such as that generally used for making or repairing roads, and I take it from the roads after it is reduced to a puddle or powder; but if I cannot procure a sufficient quantity of the above from the roads, I obtain the limestone itself, and I cause the puddle or powder, or the limestone, as the case may be, to be calcined. I then take a specific quantity of argillaceous earth or clay, and mix them with water to a state approaching impalpability, either by manual labour or machinery. After this proceeding I put the above mixture into a slip pan for evaporating, either by the heat of the sun or by submitting it to

the action of fire, or steam conveyed under or near the pan, till the water is entirely evaporated. Then I break the said mixture into suitable lumps, and calcine them in a furnace similar to a lime-kiln till the carbonic acid is entirely expelled. The mixture so calcined is to be ground, beat, or rolled to a fine powder, and is then in a fit state for making cement or artificial stone. The powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and thus applied to the purposes wanted."

The characteristic of Aspdin's invention is that lime and argillaceous clay, both in a state of very minute division, are intimately mixed together in certain proportions, then dried and calcined, and finally ground to powder. Aspdin, however, working with the materials at his disposal, calcined the lime in order to reduce it to a sufficiently divided state before adding the clay, whereas the ordinary Portland cement of commerce is now made of chalk and clay; and as the chalk can be reduced to a fine powder without previous calcination, the expense of double firing is saved, and the manufacture much simplified. Besides the artificial Portland cement (manufactured in Great Britain chiefly on the banks of the Thames and Medway, where the raw materials are abundant) there are natural cements, largely manufactured from natural marls containing about 30 per cent. of clay, in which the combination of calcareous matter and clay is apparently more perfect than in the artificial mixture, and might therefore, perhaps, lead us to expect better results. With very few (if any) exceptions, however, the best class of artificial Portland cement is stronger than that made from natural marls, perhaps from the composition of the latter being variable, or from some more obscure cause—and the author therefore confines his observations to the artificial cement made of chalk and clay.

There are two methods of making artificial Portland cement,

namely, the wet and the dry method; in the former the ingredients are mixed with the aid of water, in the latter without water. The wet method is that adopted in England. The dry method has been tried on the Continent, but with what results the author is unable to state.

The first process in the manufacture of artificial Portland cement by the wet method consists in the due mixture of the clay and chalk, which is generally effected in a circular wash-mill shaped like a huge tub, with a central upright axis to which are attached horizontal arms carrying vertical knives, the rotation of which stirs up and incorporates the materials with water, till the whole is reduced to the consistency of cream. This operation is probably the most important one in the whole manufacture, as the success of the result mainly depends on the care taken in duly proportioning and thoroughly incorporating the chalk and clay in a very finely-divided state. The usual proportions are from 3 to 4 parts of chalk (according as it is the white or grey chalk), with one of clay, by measure; and both ingredients should be as free as possible from sand or vegetable matter. The clay should be the alluvial clay of lakes or rivers, in a state of minute division; and long exposure to the air should be avoided, as this has been found to injure its quality for artificial cement.

From the wash-mill the creamy mixture flows into tanks or reservoirs in the open air, which have an area of several hundred square feet and are about one yard deep. Here the washed stuff is precipitated, and the clear water allowed to run off through suitable sluices, leaving a pasty mixture, which, after being partially air-dried, is cut into lumps and wheeled to the drying ovens, from which again it passes to the kilns, which are of a circular form, somewhat resembling an ordinary lime-kiln, and worked on the intermittent principle with coke fuel. Here again much attention is required, for if the washed material has too large a proportion of clay a

smaller quantity of fuel is required, and it is to be feared that this tempts some manufacturers to overdose with clay, which generally produces a quick-setting, but weak, cement. On the other hand, it is scarcely possible to overburn cement in which the proportion of lime is excessive. An excess of lime, however, renders the cement (especially if fresh from the manufacturer) liable to crack—no doubt from the free quick-lime throughout the mass swelling subsequently to the process of setting. For this reason it is generally advantageous for engineering works to keep the cement some months in store before using it, though plasterers are said to prefer the fresh and quicker-setting cement.

The temperature of calcination should be very high, so that the cement may agglutinate and arrive at the limit of vitrification. In this respect the calcination of Portland cement differs essentially from that of Roman and some other natural cements which are injured by being brought to the verge of vitrification. Some writers think that the sole duty of the kiln is to expel the carbonic acid from the mixture of argillaceous matter and lime; there can be little doubt, however, that the chemical combination of the lime, alumina and silex is partially effected in the dry way during the burning, and that it is subsequently carried on and completed by the agency of water; and if this be the case, the analysis of a cement stone after calcination should show the commencement of this process, by the presence of some silicate of lime and alumina. It should, however, be kept in view that a most essential condition of the paste in the reservoirs is that its composition be quite homogeneous, otherwise the portions richest in silex would fuse and form silicates which could not enter into combination with water; and this agrees with the fact that the state of incipient vitrification appears to be the proper limit of calcination. Highly burnt cement is denser than ordinary cement and density is almost invariably an indication of strength. First-

quality cement must therefore be highly burnt; but as the extra cost of the fuel is not more than one to two shillings per ton of cement, this should be no obstacle to its production when cement of high tensile strength is required, equal to engineer's test. The produce of the kiln, when made from properly mixed materials and carefully burnt, will be a clinker of a dark greenish-black colour, and reduced to about one-half the original weight. Sometimes a large proportion of dust is formed along with the semi-vitrified clinker; this dust, when mixed with water, will be of a bad colour and deficient in tensile strength.

When sufficiently cool, the contents of the kiln are crushed and reduced to small lumps and finally ground between horizontal stones, like those used for grinding corn. If the cement is not ground sufficiently fine there will be a large percentage—in many cases far exceeding 10 per cent.—of coarse unground particles, which are inert in the making of mortar and act apparently like so much additional sand. This hard granular portion, if finely ground, will set like the rest. It is probably the very cream of the cement, as it will bear a high tensile test if ground fine. In the granular form, however, it does not set, and counts therefore for nothing as cement, and is so much waste to the consumer, who thus loses a portion, which the author has not accurately ascertained, but believes considerably to exceed 10 out of every 100 tons which he buys from the manufacturer. Far too little attention has been paid to this matter of pulverization, for not only is the loss in weight very serious in itself, but this useless portion is the heaviest, and probably therefore most valuable of all the cement. In America the usual practice seems to be to grind their cement much finer than in England, so much so that not more than 8 per cent. of a cement should be rejected by a sieve of 6,400 meshes to the square inch. It is probable, however, that the American cements, produced from

natural cement stone, are more easily ground than artificial English Portland cement.

To enumerate briefly the properties of Portland cement. Its colour is a stone grey, with occasionally a slightly greenish tinge. Buff-coloured cement is almost invariably weak, and owes its colour probably to an excess of clay, or to imperfect burning. The density of Portland cement in powder varies from 1·2 to 1·4. It sets slowly, and contracts nearly 30 per cent. when mixed with water. The lime is always in excess; and the following analysis by M. Bouniceau represents the chemical composition of cement manufactured by one of the leading London firms:—

Silica - - - - - - - - -	20·84
Alumina and oxide of iron - - - -	12·75
Lime, free, or combined with some carbonic acid	4·05
Lime in combination - - - - - -	60·47
Sulphate of lime - - - - - - -	1·89
	100·00

The composition varies slightly, and the silica may reach 24, and the lime in combination diminish to 54 per cent. We may, however, generally assume that London Portland cement contains about 65 per cent. of lime and 20 of silica, and that the remainder is chiefly alumina; it also contains a little oxide of iron, magnesia, and sometimes 3 per cent. of alkalies. Indeed it is probable that all cements contain some soda and potash, derived from the argillaceous matter.

Portland cement is especially valuable in engineering operations, as it is less hygrometric and it will keep longer and bear transport better than other cements. It hardens either in air or in water, and it resists frost and atmospheric changes well. Even after being partially set, it may be worked up again, though the practice is not recommended, and as it

takes long to set when made into mortar, it does not require any peculiar skill on the part of the workmen. It bears a far larger burden of sand than hydraulic lime or Roman cement, and even when much dearer per ton than the former, it will frequently be found cheaper in reality, as it may be mixed with from two to three times as much sand. It is extensively applied to architectural ornamentation, and many of the finest modern dwelling-houses in the west end of London owe their handsome appearance to Portland cement stucco. The shipbuilder, too, largely avails himself of Portland cement for plastering the inside of the bottoms of iron ships, whereby bilge water, dirt, ashes and other corroding matters are prevented from coming into contact with the iron. In addition to its density, Portland cement is usually tested by tearing asunder small bricks of an I shape—the section at the centre being $1\frac{1}{2}$ inch square, that is the area equals $2\frac{1}{4}$ square inches. The standard which the author requires is that the cement shall weigh 112 lbs. per bushel, equal to $87\frac{1}{4}$ lbs. per cubic foot, in the dry uncompressed state of powder, and that its tensile strength shall not be less than 350 lbs. per square inch of section after seven days' immersion.*

MANUFACTURE OF CONCRETE AND MORTAR.

We shall now proceed to consider some of the ways in which cement is used, and first and foremost concrete demands our attention. To understand the qualities of concrete, we should bear in mind that mortar is a mixture of lime or cement with sand, while concrete is a mixture of lime or cement with gravel, or with broken stone and sand; and as gravel is composed of sand and pebbles intermixed, we may make concrete by mixing common mortar with pebbles or broken

* The reader will find much useful information on limes and cements in Gilmore's "Practical Treatise on Limes, Hydraulic Cements, and Mortars," and in Reid on the "Manufacture of Portland Cement."

stone ; and this method is sometimes adopted, though it has the disadvantage of requiring somewhat more manipulation than the ordinary plan of mixing all the ingredients in the dry state first and then tempering them with water. Regarding concrete, however, in the aspect of common mortar mixed with pebbles, we get an adequate conception of its properties. It is, in fact, rubble masonry, the stones of which are much smaller than in ordinary rubble work, and the theoretic mode of making concrete would be to take a box full of pebbles or small stones and fill in all the voids with mortar. If we carry this idea out further, we may view mortar as a mass of sand, *i. e.*, very small stones, with all the interstices filled up by lime or cement paste. Practically, we require a larger proportion of mortar for concrete, and of lime or cement paste for mortar, than this theoretic view of the matter requires, for it is important that each pebble or grain of sand should be completely coated with a layer of the cementing material, and to ensure this and make amends for irregular distribution of the ingredients, we put in a greater proportion of the finer materials than theory demands. Concrete may vary in quality from coarse mortar to small rubble, the quality being generally determined by locality and the greater or less facility of obtaining suitable coarse ballast, as well as by the nature of the work ; but whether the ballast be fine or coarse, it is very essential that it be free from loam and organic matter.

Where machinery is not used for the manufacture of concrete, the author finds the following the most suitable method of ensuring the proper proportions and careful mixture of the ingredients. The ballast is barrowed into a tray of rough deals without ends, generally of the following dimensions:—length 20 feet, breadth 6 feet, height of sides from 2 to 4 feet. When the tray is filled with ballast, a straight edge is passed along its top sides, so as to reduce all the ballast to the same

level as the tray, and battens of definite thickness are then laid on the top sides to gauge the due proportion of cement, which is spread above the ballast—its surface being levelled with the straight edge as before so as to agree with the upper surface of the battens. Thus, if the tray be 3 feet high and the battens 6 inches deep, the proportion of cement to ballast will be 6 to 1; if the battens be 4½ inches deep, 8 to 1, and so on. Two men then face each other at one end of the tray, and turn its contents over from end to end, thrusting their shovels along the floor of the tray. By this arrangement the ingredients are mixed in the dry state with tolerable uniformity and the men begin again at either end, incorporating the mixture with water thrown on from a bucket by a third man, in the same manner as mortar is mixed by hand. In some cases where time presses, the two first men, after gauging the concrete roughly with water, pass it on to two other men, who give it another tossing and then throw it into the foundation pit or wherever it may be used; and here it is chopped with a shovel and tamped to make it lie close, or (what is found to answer exceedingly well) a man with heavy boots treads on it, so as to compress it and squeeze out superfluous water which rises to the surface and flows off.

Besides good materials, two things are requisite to make good concrete. 1st. Water should not be used too freely, and this requires careful supervision, for a large addition of water diminishes the labour of turning over the stiff mass and therefore there is a great temptation to the workmen to use more than is necessary. 2nd. The ingredients should be very thoroughly incorporated, so as to make a homogeneous mass, and this (being very hard work) is apt to be badly done unless the labourers are very carefully watched. On this account machinery is preferable to hand labour, and several concrete mills have been invented. One of these, which the author devised some years since and has used with very great suc-

cess indifferently as a concrete or a mortar mill, may be described. Plate VIII. represents this machine. It consists of an open trough made of cast or wrought iron, 7 to 8 feet long, and 3½ feet wide. The lower portion is semi-circular in cross section and the sides above are slightly splayed outwards. Through the centre of the trough passes a wrought-iron shaft, 3½ inches square, in which adjustable blades of wrought iron are inserted, the blades being so arranged that they may have a tendency to screw the concrete forward as the shaft revolves. This can be adjusted at will by turning the blades on their axes, so as to increase or diminish their pitch. The travelling movement is also accelerated by inclining the trough in the direction of its length so that it may have a fall or slope downwards towards the delivery end. The motion may be communicated either by a belt or gearing from a 3 H.P. engine. The method of working is as follows. The gravel and cement are gauged in their proper proportions as already described, in a tray alongside, and two or four men shovel them, without further mixing, into the upper end of the mill, where the first three or four blades toss over and incorporate them thoroughly in the dry state. Water is gradually let on from a rose placed about one-third of the length of the trough from the upper end, and from that to the delivery end the mixture of the three ingredients—gravel, cement, and water—is perfected; so that the mortar or concrete as it comes out is quite uniform in colour, and the mass homogeneous in appearance. The result is exceedingly satisfactory: the machinery is of the simplest character; all the operations are open to view, and the friction is far less than in the ordinary pug mill. As the ends of the blades wear down after several months' use and become shorter, a small interval is left all round between them and the inside of the trough. This becomes filled with mortar, which sets hard and forms a lining to the trough, preserving the latter from

wear, and when the ends of the blades are renewed after several months' use—which is simply effected by welding a short piece of iron or steel to the ends, so as to bring them to their original length—the coating of mortar is readily chipped off and the trough restored to its original condition. The great advantage of this machine over hand labour consists in the facility of mixing the ingredients thoroughly and with a small amount of water. It never flags, and requires little watching, whereas labourers are apt to add an excess of water to relieve the labour of turning over the tough mass, or they add water in irregular quantities, and unless very carefully looked after, the mixture will be imperfectly made, and the mass resemble half-tempered mortar. Other machines have been applied to the manufacture of concrete — such as revolving cylinders, inside which the concrete is tumbled about till it gradually works its way to the lower end; and curiously constructed boxes, into which the dry materials are first thrown through a door and afterwards sluiced with water, when after a certain number of revolutions the box is opened and the concrete taken out. The author has not used this latter machine, but from its operation being so frequently interrupted and so much time being lost in filling and emptying it, it must necessarily be less economical than the horizontal mill, in which the action is continuous without any interruption.

As already stated, this concrete mill is equally efficient for making mortar. Indeed the author ventures to think it far preferable to any of the ordinary mortar mills, especially the pan with edge runners, which tend to grind and triturate the sand, thus reducing its sharpness and doing useless work. In the manufacture of hydraulic mortars the correct mode of procedure seems to be: (1) To have the lime or cement finely ground; (2) To incorporate the sand and lime in the dry state; (3) To temper the mixed materials as rapidly as may

be with a moderate amount of water. When the lime is not previously ground, and when therefore lumps occasionally occur in it, the edge runners have the merit of crushing these lumps, and thus rendering the mortar homogeneous. In this case only does the runner mill seem to present any advantage over the horizontal mill, while the latter is far simpler, cheaper, and more rapid in its operation, as when properly served, it is capable of turning out as much as 10 cubic yards of concrete or mortar per hour.

[December 13, 1871.]

B. B. STONEY, President,
In the Chair.

On the WOTTON LIGHT RAILWAY. By Messrs. LAWFORD and HAUGHTON.

Read by Professor DOWNING, Vice-President.

THIS railway was constructed in 1871 by the authors for His Grace the Duke of Buckingham and Chandos. It is seven miles long, and effects a junction with the Buckinghamshire Railway at Quainton Station. The latter railway belongs to an independent company, and is worked by the Great Western Railway Company.

The railway consists of a main line from Quainton to a point not far from the village of Brill, of 5½ miles long, and of a branch of 1½ miles long, joining the main line close to Wotton Mansion, and ending at Moate Farm. The whole line is constructed on land belonging to His Grace the Duke, save in the case of one or two fields.

The sleepers are longitudinal, 6″ × 6″, and about three-fourths of the lot are of that description of Norway timber, known in London as "die square;" as well as being cut from whole trees, the quality is extremely tough; it is creosoted with 8 to 10 lbs. weight of oil per foot cube, and was delivered at Quainton at 1s. 10d. per foot.

The transoms are 4″ × 6″, and have been generally cut from the waste elm and other timber of the demesne, and have been pickled in a solution of corrosive sublimate, which latter process so hardened the wood that it was found difficult to drive the tie-rod staples. All timber used on the estate

for purposes of construction is prepared in this way, by special wish of His Grace the Duke, whose experience of it is favourable. The longitudinals are connected at their ends by flat iron dowels, $3\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{8}''$, driven in edgeways, two to each joint. The gauge is preserved by the transoms being secured in position by wrought-iron tie rods, having nut and washer at each end, the connexion between transom and longitudinal being a plain butt joint, there being one tie rod to each transom, to which the rod is held by two staples.

The ballast is 15″ deep, 9″ of which is "bottom ballast"—it consists in part of rough gravel, obtained at a few miles distance—and in part of "burnt ballast" prepared on the spot, the ground here being the Oxford clay, full of fossil ostreas of large size.

The line is practically a surface line, its few cuttings and embankments in no instance exceeding 10 feet in height.

There are no bridges, all the roads, five in number, being passed by level crossings.

The culverts are of earthenware pipes; the drain pipes are of the same material, but of lesser diameters than those used for the culverts.

The fencing consists of hurdles made from waste timber grown in the demesne woods, and is of a common and primitive description, having cost about 1s. per yard forward.

The rails are of the bridge pattern, weight 30 lbs. per yard, and were rolled by Messrs. Townsend, Wood and Co., Britton Ferry, South Wales; the price was £8 2s. 6d. per ton delivered at Quainton Station; they are fastened to the sleepers by fang bolts; a fishing piece of oak, 8 inches long, connects each pair of rails at the ends; it is fitted into the hollow of the rails.

The $6'' \times 6''$ longitudinal sleepers and 30-lb. rail, fastened together by fang bolts, makes in practice a way sufficiently stiff for the work done; the bearing surface is found to be

ample for the maximum load pulled, which is theoretically not to exceed 2½ tons per wheel. The waggons are those in ordinary use on the English railways, say of 3½ tons weight average, and carrying 6 to 7 tons of freight each. As a matter of fact, waggons weighing over 5 tons each, and carrying 10 tons of coal, do occasionally run over the line, showing nearly 4 tons of weight per wheel total, instead of the theoretic 2½ tons.

The gradients are excellent and the curves fair; the steepest gradient is 1 in 60 for a length of a quarter of a mile, the rest vary from 1 in 100 to 1 in 800.

The cost of the railway was £1,400 per mile, exclusive of land.

The revenue at present is about £50 per week.

The traffic, so far, is chiefly in goods, coal, chalk for the farms, and agricultural produce generally, including felled timber; passenger traffic hardly can be said to exist.

The haulage for the first year was done by horse-power, but is now conducted by Aveling and Porter's (Rochester) locomotive engines, speed 6 miles the hour, weight 9 tons in steam, and having only a single cylinder, the driving wheels being worked by an endless chain from the fly-wheel shaft.

The cost of each engine, of which the number found necessary is two, was £360 delivered at Quainton.

Before the introduction of the steam engine two horses could pull three ordinary loaded waggons over any part of the line, except on the gradient of 1 in 60, upon which two horses could pull but one waggon.

The Duke would not allow any gauge to be adopted but that of 4′ 8½″, the standard gauge of the country. The heavy locomotive engines of the lines adjoining are not allowed to run in upon the tramway.

The *terrain* of the railway is a valley of the *cul-de-sac* type, Quainton Station lying at the open end, and the Brill

Terminus at the head of the valley, at an elevation of about 100 feet above Quainton. The village of Brill is at a much higher elevation, and lies at about three-quarters of a mile from the terminus.

The railway is axial in its relation to the valley. Wotton Mansion, one of the residences of the Duke, rests on the railway at four miles distance from Quainton, and is surrounded by pleasure grounds, demesne, woods, and shrubberies, with lakes of large size hard by. His Grace has not hesitated to carry the line in close proximity to the mansion, and it crosses two of the avenues.

The sides and, in places, the bottom of the valley are occupied by the numerous farms belonging to the Wotton estate; they are generally of the grazing class, each with its picturesquely-situated dwelling-house, offices, and plantations.

The staple articles of production on these farms are butter and milk. Immediately after the completion of the railway large milk vans were placed on the route by the London and North Western Railway, in order to place these rich milk and butter producing districts in immediate connexion with London. Three times a week, at present, these milk vans are run into the Broad-street Station of the London and North Western Railway, only half a mile distant from the Bank of England.

His Grace the Duke took a warm interest in the construction of this railway, and, doubtless, much of the economy attending it is due to the continual supervision exercised by himself.

He has, in several instances, designed the modes of construction adopted; for instance, the pattern of rail and permanent way is entirely of his own choosing. He possesses much engineering taste and ability, and has had a large experience of the construction and management of railways, acquired during his Chairmanship for many years, as Marquis of Chandos, of the London and North Western Railway.

[Read January 12, 1872.]

B. B. STONEY, President,
In the Chair.

Mr. Stoney addressed the meeting as follows:—

THE profession of civil engineering, having sprung into existence within the present century, cannot claim that *prestige* or those prescriptive rights and influence which appertain to the older professions, and the line of demarcation between the engineer and other men is so loosely defined, both by law and custom, that anyone who wishes to claim the title of civil engineer may do so without check or remonstrance. This is not a desirable condition of affairs, and though the members of the profession themselves may have an ideal standard, it wants the authority and sanction which appertain to the various titles of other professions. There are, however, certain marks or guarantees that a man is really a civil engineer which are now pretty well understood and which are applicable to nearly all who of late years have entered the profession. These qualifications are one of the following:—(1) Holding the diploma or degree of a recognized school of engineering, such as those connected with the universities. (2) Having been a pupil for at least three years with an engineer of acknowledged standing. (3) Being a member of the Institution of Civil Engineers.

The time has gone by when practical sagacity formed the sole qualification of an engineer, and though there were during the last generation some memorable names on the roll of engineers, generally self-taught men, whom great natural ability and special aptitude for their work had raised to pre-eminence in their profession, such men would now have a

poor chance of competing with their more highly educated brethren, who combine scientific training with practical knowledge. It is, indeed, of the highest importance carefully to consider what is essential for the education and training of an engineer. Hitherto it has been too much the practice to consider that ordinary mechanical tastes are enough to stamp a boy as being suited for the profession, and fond parents are sometimes apt to think that because their son prefers making rabbit hutches, boats, or such like toys to learning his lessons diligently, that therefore his tastes mark him out as a future Rennie or a Stephenson. There can be no greater mistake than this, and in no profession perhaps, now that competition has become excessive, is there so little prospect that men who are mentally deficient, or who are averse to intellectual labour, will succeed in obtaining a high position. It is true that the prizes in the engineering profession are few, and therefore there is little inducement for men of talent to select it as their profession, especially in Ireland, where their services are so poorly recompensed, nor has the treatment of civil engineers in the Public Works Department in India been hitherto calculated to draw men of ability into that service. In the earlier stages of educating for the profession we find also that, while other professional schools have prizes of various kinds offered to stimulate youthful ardour and reward merit, to the School of Engineering of Trinity College, Dublin, which has now been established for some thirty years, no prize or scholarship of any kind is attached, and this neglect of their interests has been much felt by successive students. Up to a comparatively late period the usual method of entering the profession was by becoming a pupil of some engineer in practice and having what was called the run of his office. This, perhaps, was well enough for the simpler kinds of railway engineering which had become more or less stereotyped and required

little more than a knowledge of earthwork, surveying, and masonry of the simpler kinds; but when iron structures came into fashion and when anything outside the ordinary routine had to be designed or carried into operation, we find that this amount of knowledge failed, and a demand arose for higher attainments. As the field of engineering adventure became enlarged, and harbour, hydraulic, and marine engineering became more and more important branches of the profession, it soon became evident that scientific training was quite as essential as practice, and there are few now who will venture to dispute that both combined are essential for the rising generation of engineers. Complaints have been made not unfrequently, and in some cases perhaps not without justice, that the preliminary theoretical training was superficial, and that diplomas or certificates have occasionally been awarded to unworthy men. This, I fear, is not confined to the engineering schools alone, but more or less pervades much academic education. In some cases it may, perhaps, be partly attributed to requiring men to go through too extensive a curriculum of study; but I believe the one great fault which pervades nearly all the higher branches of education in this country—and I would confine my observations to the education of the average run of mankind, for I am not treating of prize men and honour examinations—is this, that a very low standard indeed is sufficient to pass an examination and qualify the student for a further step in his college course. A loose and slovenly method of mental work is the result, and a confirmed disinclination to grapple manfully with any difficulties which may arise, but which it is easier to let slide than overcome by an accurate process of reasoning. Incompleteness and an unsatisfactory way of half doing things is the consequence, and I know of no greater annoyance than having to depend on the untrustworthy efforts of a mind thus enfeebled. The true remedy for this

seems to be to insist on an exact knowledge of whatever is professed to be learned, be it ever so small; and if men are unable to compete for honours, that is no reason why they should be allowed to pass ordinary examinations with a mere smattering of that knowledge the acquisition of which the examination professes to test. If the average man is unable to cope with an extended course, it would be far better to shorten the course and compel him to acquire a really thorough knowledge of a few subjects than let a wretched skirmishing over a wider range qualify him for passing to a higher class.

There is no doubt that in technical education we may usefully borrow much from our Continental neighbours. In the Central School in Paris, for example, we find what appears to be an excellent system of testing the comparative merits of the pupils, who are subject to frequent compulsory examination, not only at the end of each year's studies, but also during the course, and at their close. At first the council of the school, when definitively classing the pupils according to their merits, took into account only the marks obtained at the final competitive examination at the end of the third year, when each pupil had to present a project on a given subject. But experience soon showed that a pupil who answered correctly the questions put at the examination was not unfrequently a very indifferent pupil favoured by a lucky chance. It was, therefore, decided that the average marks of the third year should be added to those of the competition in appreciating the merits of the candidate. As pupils were often found to be somewhat negligent in the second year, it was subsequently deemed advisable to carry this principle still further, and take into account the marks of the second year in awarding the diploma or certificate of capacity, and in assigning the pupil his place in the list published in the *Moniteur*. With all these precautions, it is

scarcely possible that there should be any great mistake in appreciating the merits of the pupils; and M. Perdonnet, from whose report I have extracted the foregoing information, adds further, that this fact seems to have been well understood by manufacturers, for most of them require candidates for employment to produce either a diploma or certificate, and as the latter is of much less value than the former, we every year see old pupils who have obtained certificates only present themselves again to compete for the diploma.

As I have often been asked what I considered the best method of learning engineering, I shall devote a short space to this consideration. First and foremost, let the embryo engineer, after having had a liberal school education, be well instructed in those branches of science which directly bear on his future profession; and here, again, I may observe that the usual curriculum might probably be curtailed with advantage by omitting, or at least not making compulsory, some few subjects, such as crystallography and possibly mineralogy, which, though no doubt very desirable branches of knowledge in their way, are in no respect essential to the practice of ordinary engineering. The human mind being limited in its capacity, it is not desirable to make obligatory those subjects which are not absolutely necessary for the ordinary exercise of the profession—far better, as I have already urged, would it be to demand a higher standard in the essentials. If a man is intended for the profession of a mining engineer or a geologist, by all means let him learn these exceptional studies, but that is no reason why ordinary engineers should spend time over matters that are, to a certain degree irrelevant, at the expense of more vital subjects. The system in some of the Continental polytechnic schools and universities seems in this respect one worthy of imitation, viz., to allow men to take up and thoroughly work out particular branches of study, and not waste their powers over

a diffused course, much of which is dropped the moment the pressure of having to pass an examination ceases to act. An arrangement somewhat similar to this exists in the Glasgow University and in the Queen's Colleges in Ireland, and in the former it has been found to answer in cases where the winter can be devoted to study and the summer to the practice of engineering or industrial pursuits. There are also numerous instances, especially in a large city, where men would gladly attend special courses for the sake of acquiring knowledge without expecting any certificate of attendance; and it seems properly within the functions of a great teaching institution like Trinity College, Dublin, to afford enlarged facilities of this kind to any one who wishes to avail himself of them on payment of a reasonable fee, without requiring such students to matriculate. In order to gain the theoretical knowledge required for the profession of a civil engineer, it will be advisable to become a student in one of the University schools of engineering, and this course of theoretical training cannot be considered completed in less time than three years. Besides scientific knowledge the student in the schools should learn surveying, drawing and such technical knowledge of his profession as can be acquired from lectures and books. In drawing of details, especially, should accuracy be insisted on, and to each school should be attached a first-class mechanical draughtsman, one who has been through the workshops himself and has practised his calling successfully for some years in extensive mechanical establishments. This draughtsman should teach daily in the drawing-office, going round from desk to desk and, acting under the directions of the professor of engineering, he would relieve the latter of much mechanical labour, which should not occupy his time to the exclusion of more important professorial duties. After the student has gone through his three years of the school, he would be qualified to become a pupil either of a civil or

mechanical engineer, and having already a correct appreciation of theory and a mental training of a kind likely to develop habits of industry, application and observation, he would in two years' apprenticeship learn more than an ordinary pupil raw from school would in five, and when thrown afterwards on his own resources would not display that lamentable ignorance which is occasionally exhibited by those purely practical men whose scientific education has been altogether neglected. The time thus occupied in learning his business will be five years, or six years if the student takes out his B.A. degree, a thing he will have no reason to regret in after years; and if he enter college at seventeen, he may expect with due diligence to become an engineer who can hold his own and be useful as an assistant at twenty-four years of age. Of all the qualities most essential to a young engineer, and one in which a large number are very deficient, is exactness. A want of thoroughness and completeness in that they have to do is the bane of many a young man, who, in other respects, may possess qualities calculated to be useful to his employer; but nothing can supply the want of accuracy, and this is chiefly to be obtained by a patient grappling with the difficulties of each little matter that may arise and not letting it go till he has mastered all the details. The practice of this goes far to insure success—the reverse to entail failure. The idea that matters will shake themselves right in the long run is very fine in theory and, no doubt, to a great degree true in reality; but it generally will happen that the indolent and inexact assistant-engineer will also find himself shaken out of employment by this natural process of rectification in which he blindly trusts.

Connected with this subject of technical education a matter has frequently strongly impressed itself on my mind when witnessing the wasteful application of power by the labouring classes, namely, the great want of a certain amount of practical

technical knowledge being taught in the primary schools. The working classes are perpetually engaged in operations which require them to move about heavy materials in various ways both by manual and mechanical labour, but few indeed have any intelligent idea of the use of the lever, the pulley, the wedge, or the screw. As to friction, most of them seem to have no conception whatever of it, or how to relieve or mitigate its effects, and I am fully convinced that a little practical education with experimental apparatus of a very simple character and instruction in the working of ordinary machinery would be quite as useful and apt to awaken intelligence in the attendants of the primary schools as their book knowledge, and probably quite as interesting to the young learners. Now that machinery for agricultural purposes is coming into every-day use, this kind of knowledge would be quite as important for the agricultural labourer as for the navvy or builder's labourer; and it cannot be doubted that to the soldier also a sound practical acquaintance with elementary mechanics would often prove of extreme value in time of war. Having regard to the competition which we sustain from abroad in all the industries which have hitherto distinguished the United Kingdom, it seems more than ever necessary that we should endeavour to let nothing escape us which may aid in maintaining that supremacy which was so hardly won and which is now so stoutly attacked from every quarter.

Of the future prospects of engineering in Ireland it is difficult to speak with any certainty. Much work doubtless remains to be done, but, with some few exceptions, chiefly by supplementing the deficiencies and filling in the shadows of the broader lines of enterprise which have already been opened up. As regards railways in Ireland, it seems clear that there cannot be any very rapid extension of either main or branch lines for the future, for the industry of the country

is not sufficiently manufacturing to make it likely that such enterprises will meet with much encouragement. There is, however, a certain opening for cheap railways, and this subject has much engaged the attention of engineers and others since the success of the Festiniog line has awakened attention to the subject. The action of the Indian Government in determining to make the metre a standard gauge in India seems certainly a move in the right direction, for it appears very absurd to introduce costly wide gauges into poor countries when narrower ones have been found sufficient for the wants of the richest and most industrious nations in the world. It is now becoming gradually understood that a requent service of light trains affords greater accommodation to the public and a greater inducement to them to encourage railway traffic than heavy trains at long intervals, and as it generally happens that a great portion of a railway staff must be employed whether the trains run frequently or not, and as a large proportion of the cost connected with the railways is in no respect, or scarcely at all, dependent on the number of trains, it follows that the expense of a railway worked with frequent light trains, compared with that of one worked with few and heavy trains, will bear a very different ratio indeed from that of mere relative number of trains. There are few intelligent minds that have considered the subject carefully who will not acknowledge that a metre gauge, similar to that which is now so wisely introduced into India, where it will probably ultimately supersede all other gauges, would, it originally made the gauge of Ireland, have given all requisite facilities for traffic and have paid a considerably larger percentage of dividends to the shareholders, as well as have been further extended throughout the country, than the present gauge of 5ft. 3in. It may be too late to go back on the past, but it is probable that future branch lines will, to a great degree, be constructed either on a narrow gauge, or, if the

standard gauge be maintained, with a much lighter permanent way and lighter rolling stock than those adopted on the main lines. Both systems have their able advocates among the members of this Institution, and I trust they will bring the question forward, illustrated by statistics and acquired experience, which alone can render material assistance in deciding the relative merits of such questions. A few general considerations, however, may not be devoid of interest. The *bête noir* of the narrow gauge is the alleged difficulty of breaking bulk—an evil, I believe, more imaginary than real. As regards passengers and parcels, this is already done wherever a junction occurs between a branch and main line and, as regards heavier goods, there are several ways of overcoming the objection. For instance, with such traffic as coals there is no great difficulty in making the bodies of the narrow-gauge coal trucks to lift like boxes off the frames, to be hoisted by suitable cranes on board the larger trucks, as was formerly the practice with the diligences in France, when passengers were conveyed partly by rail and partly by a diligence that was separated from its wheels and then mounted bodily on a railway truck in the course of a very few minutes, without disturbing either luggage or passengers during the operation. For bale goods this may not be equally desirable, and they may, perhaps, be better transmitted, as passengers' luggage and parcels now are, by hand from waggon to waggon; and the expense of this will be less than at first sight may appear, for there must always be a certain staff of men available at junctions who might just as well be employed at this work as in doing nothing, which frequently forms their principal occupation for several hours every day. Some persons have imagined that it would be necessary to have a special local repairing shop for narrow-gauge engines and waggons, but this is altogether a mistaken notion; nothing can be easier when

a heavy repair is required than to hoist the little waggon or engine on a broad-gauge truck and run it up to head-quarters, where the principal workshops are situated. The great thing to dread with a light branch line of the ordinary gauge is the tendency of traffic managers and directors to work it with the heavy worn-out rolling stock and engines which are not considered good enough for the main line, and gradually the system will drift into that adopted on the latter, when nearly all the advantages supposed to be derived from the cheaper kind of railway will disappear, and the state of affairs will gradually become much the same as we find along our present branch lines, with this additional demerit, that the unfortunate engineer will come in for a large share of obloquy from every side—from the traffic department and directors because special rolling stock are required and, when this objection is removed by using the same stock as that on the main line, from those pecuniarily interested, because the commercial result fails to meet their anticipations.

Few circumstances afford stronger evidence of the increasing prosperity of this country than the development of traffic; and this is shown in a marked degree by the increased tonnage and demand for improvement in some of our principal ports. In Belfast we find that the tonnage which entered the port has doubled in about twenty-one years, in Dublin in about twenty-three years, while in the port of Liverpool it has doubled in twenty-five years. The respective tonnages entering these three ports and Glasgow for one year were as follows, those of Belfast and Dublin being made up to the end of the year 1870, and those of Liverpool and Glasgow being made up to midsummer of the same year:—Belfast, 1,225,566 tons; Dublin, 1,506,011 tons; Glasgow, 1,992,110 tons; Port of Liverpool, 5,728,504 tons. It thus appears that the tonnage of Dublin is about three-fourths of that of

Glasgow, and a little over one-fourth of that of the Port of Liverpool, which includes Birkenhead. This increased tonnage is also accompanied by an increase in the size of ships, and the demand for accommodation is not merely for additional length of quay space, but for deeper water alongside. Vessels drawing 22ft. of water are now sufficiently common in the port of Dublin, and all experience shows that as soon as accommodation or facilities are provided, so soon will they be eagerly seized and create a demand for more. These facts clearly prove the fallacy of the statement so often repeated, like the cuckoo's cry, that we have now come to the limit of extension of trade and industry and that we should therefore rest and be thankful. With minds addicted to this class of thought it is difficult to reason effectually, for arguments based on logical inference or experience have little or no weight with them, and they regard the well-considered opinions of more enlightened and more experienced people as the lucubrations of over-sanguine and enthusiastic fancy. On the other hand, we find a different type of mind, which, rashly jumping to conclusions, claims public support for its visionary crotchets and ill-considered schemes, and, if this be not conceded, represents itself as being in advance of the age, and therefore somewhat ill-used, though it may console itself with the hope that posterity will do it tardy justice. Now, it is the business of the engineer to steer clear of either of these extremes. His mind should be calm and free from bias or partisan views on the questions with which he has to deal; and though he should be prepared when necessary to infuse a fair share of enthusiasm into the expression of his carefully-matured ideas, he should trust to logic and sound common sense carrying the day, rather than appeals to the imagination or speculative tendencies of his clients.

This leads me to consider that most important branch of the engineer's profession which consists in preparing plans,

statistics, and other evidence for parliamentary committees. A frequenter of the committee rooms of the Houses of Parliament cannot but be struck with the immense labours of those members who devote not only their evenings and nights to legislation, but spend from four to five hours of the day-time in the investigation of the merits of local or private bills with rare patience, and, generally speaking, great tact and an intelligent recognition of the duties they have to perform as combined judge and jury. Though the chairmen of these committees are selected for their high qualities, yet one cannot but sometimes feel that their want of professional training and experience often leads, not only to great waste of public time and expensive and protracted contention between opposing interests, but that occasionally also there is a certain failure of justice owing to the absence of an unbiassed professional assessor, who would at once detect inconsistent or partial evidence and confine the professional witnesses to their proper functions of stating facts, and not becoming advocates. It may, perhaps, be said that under the present system any loose points on either side will be detected by the cross-examination of the opposite party. This, no doubt, will often occur, but it also sometimes happens that one side fails in procuring such weighty evidence as the other, either from poverty of means, or what is, perhaps, fully as common a cause, the question being one of little interest to private individuals, and then it happens that that which is every one's business is neglected by all. An assessor such as that described should hold a very high rank in his profession for intelligence, experience and rectitude of purpose; and as it would be incompatible with his duties as assessor that he should continue his private practice, it would be necessary to attach such a salary to the appointment as would compensate for this loss and render the post one desirable of attainment by the highest members of the profession. Two such assessors

with well-selected committees would probably be sufficient to get through the more important private business of each session, and there can be little doubt that the result would be beneficial to the profession at large. We should find less special pleading and less disregard for strict veracity than is now unfortunately sometimes found in the advocacy of professional men, and such appointments would be very beneficial in consolidating the influence and elevating the status of the engineering profession. The relief to members of Parliament would be very great indeed, for the vast expenditure of time and labour in morning committees, which now form so heavy a tax on their energies, would be greatly diminished, and their work would, not only be quicker, but it would be better done.

Of late years sanitary engineering has taken a very conspicuous place, both on account of the vital importance of the subject in a public point of view and, perhaps, to a certain extent in consequence of the diminution of railway construction leaving the fertile minds of the profession freer to seek new paths for their enterprising skill. At present we see isolated and desultory efforts to free the great centres of population from the dangers arising from concentrated masses of mankind; and as villages creep into towns, and towns into cities along the valleys of the sister isle, we find the question perpetually giving rise to parliamentary and royal commissions, hasty legislation but half enforced, injunctions and cross purposes, each little township or district looking to its own interests only and generally ignoring those of lower populations on the same stream, while vast expense is incurred and abortive attempts are made to palliate the evil, in place of boldly grappling with the question and facing the difficulty at its source. The method, then, which seems to recommend itself as the most likely to succeed in producing general good results is to form a drainage board or commission for each main river valley,

extending from its source to its outlet in the sea, and embracing within its jurisdiction the whole of the tributaries, and the area which discharges its waters therein. This board might be formed of representatives of the various interests concerned. and have one or more paid commissioners appointed by Government to prevent the weak from being overtaxed by the majority. Where, as occurs in many valleys in the manufacturing districts in England, village after village and town after town rise along the banks of the same rivers and its tributaries, it seems probable that it will be found necessary to construct a great main drain or sewer parallel to nearly the whole length of each stream and intercepting in its course all the sewage which would otherwise pollute the water. At suitable places along its course this intercepting sewer should be tapped for purposes of irrigation and thus greatly diminish, or under favourable conditions altogether remove the sewage in the best method hitherto devised. If hereafter any plan of deodorizing or otherwise manipulating the sewage be brought to perfection, it can also be adopted at suitable places along the intercepting sewer remote from the thickly-peopled localities.

In mechanical engineering three things have occurred during the past year which are of vital interest to a great manufacturing and commercial country like England. First, the diminution of the hours of labour among the working classes. Secondly, the enormous extension of the iron manufacture and the great demand for hematite ores for Bessemer steel. Thirdly, the increased cost of coal and the growing feeling that the supply may possibly not equal the future demand, and that there will result a future increase in prices that may render some branches of manufacture unprofitable. The improvement in the material prosperity of the working classes, especially those exercising skilled labour, has been very marked during the last quarter of a century,

and the shortening of the hours of labour, which has been lately so successfully established, is another step in the same direction. Part of this prosperity may, no doubt, be attributed to the influence of large gold discoveries on the price of labour; but still, comparing their relative position with that of other classes of society, the balance on the whole seems in favour of the operative. Now that education is within the grasp of all, and that fresh facilities are constantly given for a lad of talent to work himself up by his abilities from each grade to a higher one in the scale of learning, we find that competition in the professions and the higher branches of business has greatly increased, while incomes derivable from professional toil have not at all augmented in the same ratio as those derived from manual skill. On the other hand, we find the cadets of noble houses contending in the same arena with members of the learned professions and men of business; so that on the whole we may conclude that what are sometimes called the upper middle classes in society are those whose relative position has least altered for the better within the last quarter of a century.

The stagnation of trade which succeeded the year 1866, having passed away simultaneously with the expiration of the Bessemer patents and the termination of the Franco-German war, has given an immense stimulus to the manufacture of iron. To the engineer everything connected with iron is replete with interest, but we fear our long cherished hopes that steel plates may be manufactured in large quantities of a reliable and uniform character has not yet been realized. In shipbuilding steel is still regarded with distrust, and this must be so long, as its tendency to fly without warning has not been overcome by the manufacturer's skill. Iron, therefore, still reigns in the construction of ships and in no other branch of trade is greater activity at present

displayed. Long screw steamers, high-pressure steam and surface condensers are now the fashion, and a new timber ship is quite as rare as an iron one was twenty-five years since. Among other causes the opening of the Suez Canal has contributed to increase the length of screw steamers, and we find vessels from 350ft. to 450ft. long becoming very numerous, and one of our most experienced shipbuilders has informed me that he anticipates that vessels of 500ft. in length will be required before long for ocean routes. Thus we find the old-fashioned docks in some of our greatest ports daily becoming inadequate for the increased size of ships—an instructive lesson to modern engineers not to provide merely for the immediate wants of the present moment, but look into the future and design their works so that at all events they may be capable of extension without destroying or rendering useless work already done.

The increased cost of coal is one of the most vital interest to England, and some persons think we should not be so liberal in supplying foreigners with a commodity of which we have a certain kind of monopoly as well as a limited supply. They propose placing an export duty on coal, similar to that which the Peruvians have placed on guano, and from which the latter derive a very considerable revenue. Without going into this question, we can clearly see that the cost of fuel in England must greatly increase as the more easily won coal becomes exhausted and we have to work deeper and, perhaps, thinner seams. 4,000ft. appears to be the limit of depth at which those who have investigated the matter consider we may mine for coal. Raising the mineral from so great a depth must, however, be attended with a vast increase in cost. For example, a wire rope of this length and of uniform size would not safely carry its own weight in regular work, much less support a heavy box of coals in addition. The total lift, therefore, must be

subdivided into perhaps three or more separate lifts, and this alone will inevitably add considerably to the cost of fuel.

The most memorable event in the progress of foreign engineering during the past year is the completion of the Mont Cenis Tunnel, which is mainly due to the enterprise and intelligence of the Italian Government and its engineers. The construction of a tunnel beneath so great a depth of superincumbent rocks opens out some interesting questions to the geologist as well as to the practical engineer. The greatest height of the mass of Alps over the tunnel is stated to be 5,307ft., and at the rate of 13 cubic feet to the ton, this is equivalent to a pressure of a little over 400 tons per square foot at the level of the tunnel, which is greater than the crushing strength of many rocks, and closely approaches that of the hardest granites. At first sight it might be supposed that this enormous pressure would cause the tunnel to collapse, or, at all events, that the lining rock would be very apt to splinter, just as occurs with samples in a proving machine, long before the absolute limit of crushing is reached. There can be no doubt that before the tunnel was pierced the rock was subject to a very enormous pressure, but it seems highly probable that as soon as a hole was formed through the rock a slight motion took place, the rock expanding into the tunnel where the pressure was relieved, so that there is a tube or annular portion of rock around the tunnel, the interior of the tube being comparatively free from strain, which gradually increases the further it recedes from the tunnel, until at some short distance the full pressure of 400 tons per square foot is attained. Tresca's experiments on the flow of solids lead us to conclude that even rock may slowly close in under prolonged excessive pressure, provided the latter be sufficiently great. Possibly rock will not flow; it may rather be first crushed to

fragments and then made again to cohere by pressure within a limited space, just as certain kinds of compressed bricks are formed by forcing powdered clay into moulds. This question may possibly meet a further solution in a large practical way should tunnels be formed beneath much higher Alps than Mont Cenis, and nearer home the question attains a certain amount of interest in connexion with our future deep mining for coal; for where clay or soft shaly matter occurs in very deep mines, there can be no doubt that serious difficulties may arise from the "creeping" of the floor or roof, which is at present sometimes very sensible in comparatively shallow mines. To the geologist such speculations are replete with interest. They lead to the inference that large voids cannot exist far beneath the earth's surface. It is conceivable, however, that the contraction of solid or fluid matter may leave spaces of considerable area filled with gases or vapours in a high state of tension, and that this tension slowly diminishing may cause the equilibrium between the gas pressing upwards and the superincumbent earth pressing down to be destroyed, and thus large areas of the earth's surface might cave in suddenly. It would be a necessary condition of this latter phenomenon that the gas or vapour-filled space should not be in connexion with a lofty volcano, for the pressure due to the liquid head of lava in volcanoes such as those of the Andes cannot be much less at the level of the sea than from a 1,000 to 2,000 tons per square foot; and if lava be as dense or denser than the average mineral matter of the globe—and we are told that stones float on lava—this excess of pressure will extend downwards with an eruptive force throughout the whole area of the molten lake or internal reservoir from whence the lava issues forth. From this consideration we might deduce a minimum thickness of the earth's crust, supposing that it were a spherical shell with a fluid centre, for the outward pressure due to the liquid head of lava above

the earth's surface would be balanced by the tensile strength of the spherical shell; and if we knew the density of lava as compared with that of the earth's crust, and the tensile strength of the latter, we could readily find the thickness of the shell requisite to balance the bursting effort due to the head of molten matter. We may extend our speculations still further and conceive that the sudden upheaval of large portions of the earth's surface, such as that which occurred in Chili in 1822, and which raised the ground over an area estimated at 100,000 square miles, and to a height of 3ft. on an average, was due to the liquid head of lava in the adjacent volcanoes overcoming the cohesion and weight of the earth's crust, either by forcing itself in a horizontal direction through the solid ground beneath the raised area, or, if a large lake of molten matter exists beneath those regions in connexion with these volcanoes, by the liquid pressure over the area of this lake overcoming the superincumbent weight and cohesion of the ground around its edges. In either case the movement would cease as soon as the volcanoes were relieved by the discharge beneath of their molten contents; and as the mass thus added to the continent has been calculated to have contained fifty-seven cubic miles in bulk, which would be sufficient to form a conical mountain two miles high (or about as high as Etna), with a circumference at the base of nearly thirty-three miles, it must have taken the fluid contents of several volcanoes in the Andes to effect the upheaval. A similar hypothesis might explain the sudden caving in of large volcanoes such as that of Papandayang in Java, in 1772, when the greater part of the mountain fell in and disappeared over an area of fifteen miles long by six broad, in consequence possibly of the liquid core being suddenly removed by discharge from below, and thus leaving the interior of the mountain without its ordinary support.

[11th December, 1872.]

ROBERT MANNING, Member of Council,
In the Chair.

On the VARIOUS SYSTEMS *of* PERMANENT WAY.

By JOHN CHALONER SMITH, Member.

IT is proposed in the following remarks to lay before this Institution the results of the author's observations on the various systems of Permanent Way generally used in these countries, and about the comparative merits of which considerable difference of opinion exists amongst the members of the profession.

It is not intended to enter upon the manufacture of iron and steel, or theoretical questions relating to traction, either of which matters would occupy very much beyond the time at our disposal.

Probably to many here this paper will present nothing new, but the importance of its subject will be admitted when it is considered that the expenditure on Permanent Way, more than any other one item, affects the amount of the returns received by the owners of the vast capital sunk in railways. A judicious selection of way in the first instance, or a judicious treatment of an existing way, will save the railway company many thousands of pounds; and no error or mistake can be thought trivial when its frequent repetition occurs — for instance, a mistake in the jointing of the rails will increase to 5,000 mistakes in ten miles of line.

It is now a little more than a hundred years since iron rails were first used in these countries; then, and for long afterwards, they were merely employed for the purpose of facilitating the traction, by horses or men, of waggons containing

coal or other minerals, They were simply formed of a flat bar of cast iron, with an upright ledge for the purpose of keeping the wheels upon the line of the bar, and were fastened by pins to wooden supports or sleepers, which were sometimes cross, or stretched across the breadth of the railway, and sometimes longitudinal, or running along under each rail. It may be remarked that, as early as 1797, stone supports were used instead of timber at a colliery near Newcastle-on-Tyne.

About ten years before this a railway had been formed at Loughborough, the rails being cast iron, of a tee-shape on a flat base; and as this rail presented no means of keeping the wheels upon it, a flange was cast on the latter.

The first of these systems was styled the plate rail, the second the edge rail, and each system was vehemently backed by the rival engineers of that day. It is hardly necessary to mention that the plate rail (a line of which is still in existence not far from us, leading from the Killiney quarries to Kingstown Harbour) has been now almost totally abandoned; even the tramway rail now in our streets, by its adoption of the principle of the flange on the wheels, becoming an edge rail—although its shape certainly rather resembles the flat portion of the plate rail.

Before the end of the last century, instead of the flat base to the edge rail, chairs were sometimes adopted.

The next great discussion which arose was as to the advisability of retaining cast iron as the material for rails, or of using malleable or rolled iron. To the latter it was objected that, the rails being fibrous, the wheels would gradually expand their upper surface and cause its separation into laminæ; and although malleable rails have been universally adopted, those accustomed to inspect lines are quite aware that the objection was well founded and by no means groundless—such as another made at the same time, which was that malleable iron rails would shortly rust away,—the fact being

that (owing probably to the vibration caused by passing loads) there is scarcely any appreciable loss on our railways from this cause.

When, in consequence of the successful application of steam to locomotive engines, it became evident that railways were about to become the general means of transport both for passengers and goods, the foremost and ablest engineers directed their closest attention to the improvement of Permanent Way, and a large number of ingenious arrangements were proposed, and several tried; practically, however, resulting in the adoption by the great portion of the heavy-traffic English and Scotch lines of the double-head rail in cast-iron chairs—with, however, the remarkable exception of the Great Western line, on which Brunel (besides differing from the other railways in the matter of the gauge) used as permanent way longitudinal timber bearers, and a low and wide-based bridge rail.

As was to be expected, numerous errors were made, in consequence of the comparatively short experience which these engineers possessed; for instance, in order to attain thorough solidity and permanence, *stone* blocks were employed as supports, and (supposing that these would be perfectly stable) fish-bellied rails were placed upon them; and on the Great Western Railway piles eight feet long were driven with transverse bearers across both lines of rail, in order to procure an upward pressure.

In Ireland the principle of a bridge rail on cross sleepers was adopted by Sir John MacNeill, and more than half of the railways now in existence here were laid on that system.

In order to obviate the loss caused by the decay of timber in permanent way, a system (called, from its inventor, the Barlow way) was adopted to a considerable extent; in this no timber was used, the rail lying directly upon the ballast.

More recently the flange—or as it is frequently termed, the

Vignoles—rail on cross sleepers has been extensively used, and has met with much support from engineers; its first cost being lower than that of other systems, and its making (with the aid of fish joints) a very smooth running road, are reasonable causes for this support. The fish joint has been applied with equal success to the double-head rail, and has entirely supplanted the joint chair originally in use with that system.

It would be impossible to recapitulate the numerous proposals for so-called improvements connected with railways; indeed the seeming simplicity of the thing appears to have beguiled many persons of a certain degree of ingenuity, but of imperfect experience, into thinking that they had made wonderful discoveries, for which they have hastened to take out patents, but on examination their ideas have been found impracticable, or even erroneous.

At the same time it is by no means asserted that improvements are impossible—on the contrary, every form of way has defects, several of which may be capable of diminution or removal, and it is likely enough that many real improvements are lying dormant—like the fish-joint just mentioned, which was overlooked for many years; but inventors should not be led by fancy or prejudice, but should test their ideas, whether they really remedy the defect, whether they do not cause some other defect of a different kind, and whether their application is cheap and easy.

In order to estimate correctly the merits and defects of any form of way, it is necessary to be acquainted with it, not only when it is new, and everything sound and ship-shape, but also after it has been laid ten or twelve years, and carried its millions of tons; a comparison, therefore, between new and old lines is manifestly absurd, and were it not that it is frequently made, the mention of the matter would be superfluous.

The Brunel way was designed, and with success too, to afford continuous elasticity under the passing loads, and to

economize iron by enabling rail and timber to act together as a girder; the extra length of the cross sleepers, if used with broad gauge, would also have been a reason against them; they, however, better preserve the gauge and cant of the rail; the rail joints of this way are also defective, but its principal drawback in maintenance is the difficulty and expense of shaping and fitting the joints and transoms of the timber substructure.

The same general principle was adopted on the Croydon, the Midland Great Western, and other lines, using a flange instead of the Brunel rail. A variety of the system was also tried by making the longitudinal of triangular section, carrying on top what was called a saddle-back rail, the flanges of which inclined downwards on the sides of the timber.

The Barlow way has been very fairly tried, and has resulted, as candidly admitted by the inventor himself, in failure —caused principally by the want of elasticity which timber affords, and by the hardening of the ballast within the rail into a mass like concrete. The temptation to try the system, however, was almost irresistible, for not only did it remove the glaring evil of rotting timber, but by riveting the joints and ties, it also did away entirely with the necessity of movable fastenings, being in fact one continuous frame from end to end—at least from one set of points to another, these not having been constructed out of this form of rail.

Although neither of these systems are likely to be used again here, they should not be thrown aside altogether as obsolete, for it is easy to conceive circumstances under which their use would be attended with great success; for instance, the Brunel way would be applicable in localities where shaped timber was plenty and iron scarce, and the Barlow way in dry, sandy soils, where it might possibly supersede the Greaves' patent—or, as they are called, the pot sleepers—particularly,

perhaps, if a thin plate of iron were fixed underneath, across the base of the rail.

Most other varieties of way (so far, at least, as yet discovered) class themselves under the heads of the chair, the bridge, and the flange—some combining their principles, such as the form known as the Sandwich rail, which is a kind of hermaphrodite, partaking of the nature both of the chair and flange forms; and there is also considerable difference existing in practice in the details of the sections.

All these forms are designed to be used with cross sleepers, in procuring which the engineer must be guided by the circumstances of the case. In this country larch (when hard grown, and felled in winter months) makes a good sleeper; but as it cannot always be obtained, fir and foreign timber are extensively used. The durability of these latter will be much increased by the use of creosote—care being taken that the oil is of good quality, and that the sleepers are dry and absorb 8 lbs. to 10 lbs. per cubic foot.

Attention must also be paid to the accurate preparation of the rail-beds, so that the rails will bear evenly and be free from any rocking motion; the holes for the fastenings also must be true to gauge.

The advocates of the double-head form claim for it superior strength and stability, as well as economy; for although more expensive at first, the rail can be turned and used again, instead of the entire relaying necessary with other forms.

On the other hand, it is asserted that it is a complex, nearly obsolete arrangement, consisting of an unnecessary number of parts; that practically it cannot be turned, as it is liable then to break; and even if it does not break that it is so indented by bearing on the chairs as to cause a jolting most unpleasant to passengers; that the keys are constantly falling out; and that the fastenings on several occasions have caused accident by giving way altogether.

The facts appear to be that its greater depth makes it considerably stronger as a girder than the other forms, particularly when the latter have holes in the flanges. Perhaps this would not be of so much consequence, did it not permit the rail to be made of a harder and more crystalline description of iron, without greater danger of breakage, and with much advantage as to wear.

The stability (by which is meant the power of resistance to a force applied at the top to overset the rail) can fairly be estimated by the ratio of the height to the base, in this instance about 7 to 12; the bridge being $3\frac{3}{4}$ to 6, or about $7\frac{1}{2}$ to 12; and the flange being $4\frac{1}{2}$ to $4\frac{3}{4}$, or over 11 to 12. This force comes into action most frequently when a train is passing round a curve, and the flanges pressing against the inner shoulder of the outer rail; practically the pressure exerted is by no means equal to the centrifugal force of the train, as it is counterbalanced to a great extent, though not entirely, by the insistent weight of the train itself, which causes the rails to bear firmly on the sleepers, and relieves the fastenings from much strain.

The wooden keys in hot weather are liable to fall out; other descriptions have been tried, but have not supplanted the wood. If these keys are made sufficiently long, and well compressed, no serious inconvenience will result. A small peg or nail towards the narrow end of the key will catch the chair jaw and prevent the key from going back. It is to be noted that stability does not depend altogether on the key, as the rail is firmly held at the bottom by the inside jaw of the chair; in England some engineers use keys on the inside instead of the outside of the rail, which bears directly against the outer jaw of the chair.

Chairs permit of the use, for fastenings to the sleepers, of compressed oak treenails, which possess two great advantages over iron spikes—by not being liable to draw out or become

loose, and by having much less tendency to plough through the fibre of the sleeper. On the other hand, there is no doubt but that accidents have occurred by the treenails being sheared across, permitting the chair to slide on the sleeper; this defect is modified by rounding the inside arris of the treenail hole in the chair, so as to give it less of a cutting edge, and also by boring the treenails in the centre, and driving in an iron spike.

Chairs are also fastened—as flange rails—with iron spikes, wood-screws, or fang-bolts. Spikes are liable to become loose, especially when the timber of the sleeper begins to decay; wood-screws and fang-bolts are apt, if there be any rocking motion in the rail, to become cut across in the neck, and the thread of the latter after a time becomes stripped; when new, and the timber sound, it is the most secure fastening of any, but is open to the great objection of its being necessary to remove the packing from under the sleeper when putting on the fang, taking much time, and loosening the bed of the sleeper.

There is considerable diversity in chairs; some have two ribs on the sides, with the hole for the fastening between; some have only one rib, with the holes on alternate sides. This chair was invented many years ago by Messrs. Ransome and May, and it has the advantage of both fastenings not being in the same fibre of the timber. Care must be taken to give ample strength under the rail where the chair is most liable to break, and this would be a point in favour of wrought iron chairs, were they not so expensive and comparatively devoid of weight, which adds steadiness to the road.

On a short line now being relaid, the chairs are made to be fastened with a treenail on the inside and a spike on the outside, and the same is done upon some great English lines—the chair being wide and having four fastenings. The large area of the base of chairs gives them an advantage over flange

rails; for by distributing the weight over a larger surface the sleeper is not so soon cut into, and consequently lasts for a longer period.

Some idea may be formed of the differences of opinion existing as regards the question of turning rails by perusing the discussion on Mr. Price Williams' paper, "On the Maintenance and Renewal of Permanent Way," read at the London Institution in March, 1866; but in that discussion some of the following facts do not appear to have been touched upon.

The iron rails now made are inferior in a surprising degree to those made 20 or 30 years ago, and they appear to be deteriorating still more every year; indeed were it not that the so-called steel rails possess in a great measure the qualities of the old iron ones, there would be a most serious prospect for lines of heavy traffic. This bad iron commences to show soon after being laid down by lamination, and by short portions of the wearing surface flattening out and lowering down, from there being at these spots no weld between the fibres of the iron. If this occurs to bridge or flange rails, they must go to scrap; if to the double-head, by turning, these spots will lie between the chairs on under side, and the new upper surface will give a second chance, and the rail perhaps do its work as well as the rest after all.

When these rails (either from the sleepers at the joints being unsound, or badly packed) assume a humped or bowed form to any great extent, they should not be turned; nor should they be turned when the upper surface is so worn as to be seriously weakened and not to fit the chairs properly, and in this case there will generally be considerable indentations on the under side.

These objections, however, do not apply to a systematic turning of the rails on a well-maintained line, before the upper surface is considerably worn down or the under surface indented, and when this has been done the rail will have as

long a life before it as a new similarly-headed one of Vignoles section, and the double head may fairly claim as additional life the period during which the first face remained up. In the chair already alluded to a small recess has been formed at the bottom of the outer jaw, under the key, which will hold a little wrought iron tee-shaped plate under the rail when turned, should it be found requisite to make up for the wearing down of the first surface.

The indentation of the under surface will not be found so great now as with the hard chilled chairs made some years ago, and it may be diminished also by rounding the edges of the chairs: to obviate it, wooden cushions under the rails have been tried, and also chairs made to hold the rail suspended between the jaws. The latter has the disadvantage of not permitting the rail to be turned in or out of the chair; if turning be required, either the fastenings must be cut and the chairs threaded off the rail, or the chairs broken and replaced by new ones.

The objection taken to the double-head, that it is formed of a greater number of parts than the Vignoles, appears somewhat frivolous. If many fang-bolts are used with the latter, the difference does not exist; and if the argument were sound and conclusive, the Barlow way would be the best. When laying the double-head the plate-layer chalks on the rail the position of the chairs; these are then keyed on, and the placing on the sleepers and fastening to them afterwards is as simple as with the flange rail. After being laid, the keys have to be looked to in the one, and not in the other case; but on the whole the double-heads are not found to be more expensive than the Vignoles in the labour either of laying or maintaining.

In comparing the first cost, much will, of course, depend on the particulars of the design and on the locality. Makers generally supply double-heads some shillings per ton cheaper,

and they are also worth somewhat more as scrap when worn out. If the Vignoles be somewhat heavier than the others, the way altogether would cost about 10 per cent. less; if, therefore, 40 or 50 per cent. more wear can be got out of the latter, the economic values are apparent.

Curiously enough, much of the ground of this dispute was covered in the controversy which occurred some twenty-five years ago between the advocates of the double-head and those of a single-head rail in cast-iron chairs; the former, however, held its own, although the latter was successfully tried on several lines.*

The bridge rail, except in the form used by Mr. Brunel, is almost unknown in England; it nevertheless makes a safe and steady road, allowing its upper surface to be nearer to its base than any other form. This want of depth makes it somewhat more liable to break, but this can be counteracted by an additional sleeper, and by not punching holes in the flanges.

For several years the joint of this rail was very defective, but this drawback was removed by the joint invented by Mr. Harty, member of this Institution, and described in a paper read here in May, 1859.

The wheels of railway rolling stock being keyed on to the axles, it is necessary to make the tires of a conical form, to enable curves to be smoothly traversed; and therefore the rails are laid with a cant inwards, as shown, so as to present their surface to the tires. This cant is of great importance to the even wearing of the rails, and in the flange forms it gives the rail a power of keeping gauge independent of the fastenings: as a trial, several lengths of this bridge rail, with the Harty joint, were laid and safely run over, without any fastening between the rail and sleeper. In the double-head the cant is almost always given by means of the chair, and

* See Bree's "Railway Practice," Third Series.

this, when rectangular sleepers are used, removes the necessity for cutting through the skin of the sleeper, and tends to prevent decay.

The bridge form of rail, more than any other, permits of the advantageous use of a wide wheel-tread. The shoulders are generally turned with a $\frac{1}{4}$-inch radius, and the tread is $2\frac{1}{4}$ inches; in the others the shoulders are turned with $\frac{1}{2}$-inch radius, and the tread is only $1\frac{1}{4}$ inches, and this cannot be materially increased without widening and weakening the sides of the head.

Most locomotive engineers prefer a wide wheel-tread, under the impression that it saves their tires; but even if this be the case it might not be good economy to sacrifice a more durable head in the rail for the sake of greater durability in the tire.

In the discussion on a paper on the manufacture and wear of rails, by Mr. Sandberg (read at the London Institution in March, 1868), an eminent civil engineer advocated increased width of head; but in the same discussion reasons had been advanced against it by Mr. Conybeare.

In the author's practice he has found the narrow head to be the smoothest running and to give the best wear, but it is difficult to ascertain how much of this may be due to a harder quality of iron. Altogether the question seems one very desirable to sift by experiment, and a means of carrying this out is offered by the testing machine invented by Mr. Price, member of this Institution, and described by him in an able paper read at the London one in April, 1871.

In first cost the bridge may be considered as intermediate between the other two.

The Vignoles rail has been mentioned as inferior in stability: practically this does not much affect it in straight lines and in curves is shown not so much by the rail oversetting—although this has occurred — as by a general tendency to

become wide for gauge. This tendency can be corrected by strong fastenings, or by cleats fixed to the sleepers and bearing against the outside of the outer rail of curves; and it can be removed by considerably widening the flange—and this will be attended with the additional advantage of making the rail less liable to cut into the sleeper. It would of course add to the cost, and be quite useless between the sleepers, as it has not been proposed that the flange should bear on the ballast, and the greater width would not add vertical strength in proportion.

A rail is worn down by the weight of traffic run over it; their life, therefore, on heavy-traffic lines is comparatively short; on light-traffic lines—and by light it is not meant that the engines and vehicles weigh less, but that trains of the usual weight are less frequent—the life is so much longer that if compound interest be calculated on difference of first cost, the economic values before alluded to will approach much more nearly.

In remote or foreign districts, the Vignoles has the advantage in the freight and cost of transport being less, and also by the low values there of the chairs when broken. In England the cost of recasting these is about 20s. per ton, and some companies do it for themselves.

No hard and fast line can well be drawn to fix the exact amount of traffic above which the double-head is the best, and below which the Vignoles is the best; but unless under some very exceptional circumstances indeed, the author believes that traffics over single lines under a quarter million tons (including dead-weight) per annum will be best suited by the Vignoles, those over half a million by the double-head—the intermediate quarter million to be considered either way, at the discretion of the engineer.

It is claimed for the Vignoles form that the foot can be made fibrous to protect the rail from breaking, and the head

hard and crystalline to stand wear. In practice, at present, that foot will generally be found (the specifications of engineers and the falling-weight tests having made it requisite), but the hard head is seldom forthcoming: perhaps the makers think things should not be made to last too long. The difficulties of manufacture, indeed, are great—the different irons require different temperatures, and it is very hard to make a continuous weld between them. Should this ever be thoroughly overcome, the entire aspect of the question will be totally changed, and the Vignoles form will occupy a very much higher position. Perhaps then a further step might be taken, and worn-down rails successfully retopped; but it seems as if, in the present state of our knowledge, the practical path of improvement did not lie in the direction of a compound rail at all, but rather in that of a homogeneous rail —such as the best Bessemer steel—combining hardness and tensile strength evenly throughout its mass; and to obtain the utmost possible advantage from such a material, no form of rail is so well suited as that of the double-head.

[10th December, 1873.]

ROBERT MANNING, Member of Council,
In the Chair.

On the IRON SIPHONS *at the* WEXFORD SOUTH RECLAMATION.

By W. G. STRYPE, Member.

THERE are few operations within the province of the engineering profession that are so full of interest as works connected with the reclamation of land from partial submersion, due to inroads of the sea caused by tidal influence—and especially in this country, where there exists a rich field for operations of this nature. There was, perhaps, no situation so favourable for such works as that of the slob lands at Wexford Harbour, where, on each side of the estuary, a large surface was submerged, and only during high tides. In the year 1846 a plan for extensive reclamation was prepared for this locality, subsequently resulting in some 4,600 acres of otherwise useless land being rendered fit for cultivation, by the execution of extensive works on the north and south sides of the harbour. The object, general arrangement, and observed results of these works formed the theme of an able and exhaustive paper, read before this Institution on the 10th December, 1862, by Mr. W. Anderson, and will be found in the Transactions, Vol. VII., p. 102. This paper is so complete, and gives such full particulars of the nature and extent of the works executed, that it is unnecessary now to enter upon them.

In the South Reclamation there were three timber-framed sluices in the original work (shown in dotted lines in cross

section, see plate IX), placed at or near the centre of length of the embankment, in the vicinity of the deeper water called Coal Channel; these worked satisfactorily until the early part of the year 1868, when they began to leak and allow the water to return when the tide rose on the outside. Upon a careful examination (in which the services of a skilful diver were engaged) in August, 1868, the timber work was found to be so considerably injured by worms, and otherwise decayed, as to require complete renewal. Owing to the advanced time of the year, this became rather a serious question, and added very much to the risk of accident, in cutting down the embankment at its highest part, and in the region of the severest action of waves. There was also a difficulty in constructing a satisfactory coffer dam on the outside, since a great quantity of loose stones had, in the construction, been deposited, to give stability to the work, and to protect it from injury from the action of waves, At this juncture the opinion of our then President, Mr. B. B. Stoney, was taken; and upon his recommendation it was decided to close up the old sluices, and erect in their stead two wrought-iron siphons. This alternative presented many obvious and great advantages—which, even in the designing of new works of this nature, are well worthy of consideration when compared with any ordinary system of sluice—such as avoiding the necessity of temporary dams, and risk of endangering the safety of the embankment from leakage around the sluice channel (a great cause of trouble), and in any case removing the danger, of weakening the structure of the embankment. The siphons can also be examined at any time, and repairs (or when necessary, renewal) readily effected. In the present case there was the further advantage of the work being satisfactorily carried out at less cost than the renewal of the old sluices would have amounted to. There is an apparent objection to the siphons

that, owing to the channel being longer and containing bends, the discharge is lessened; but this is more than counterbalanced by the other advantages, and a small increase in area will at once make up for other losses.

The whole of the new work was executed by Messrs. Grendon and Co., of Drogheda, in the early part of the year 1869, being subject to the immediate superintendance and approval of Mr. Farrell, M. Inst. C.E.I., of Wexford. The cost was about £500. Since this time the siphons have continued in operation, and given entire satisfaction.

Plate IX. shows the arrangement of the siphons and their relative position on the embankment; each has a total length of about 72 feet, measured along the centre line in vertical longitudinal section, and is constructed in seven lengths, each about 10 feet long, as shown; the lengths being united together by angle-iron frames at each end $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{8}$. The clear section, or opening, is 7 ft. wide and 2 ft. 6 in. deep, equal to $17\frac{1}{2}$ square feet area. The curves are made of large radius, to render the flow as easy as possible. The plating is $\frac{1}{4}$-inch thick, with lap joints, and in a direction so arranged as not to present the edges of the plates to the flow of water outwards. The rivets are $\frac{1}{2}$-inch diameter, and spaced two inches apart centres. The angle irons in corners are $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{8}$, and the four lines of longitudinal stay angle irons are of same section. There are ten distance stays in each length of tube, made of round iron $1\frac{1}{4}$ inches diameter, with the end palmed out and secured to the longitudinal angle irons by two $\frac{5}{8}$-inch diameter rivets in each. The plan of constructing the siphons in comparatively short lengths had the advantage of enabling the most important parts of the work to be properly constructed in the workshop, where they were tested and proved staunch before sending away, and by anticipating this work, reducing the cost more than the extra expense of the angle-iron uniting frames. Indeed contractors

should always aim at reducing the amount of work to be performed on the site of erection, and especially in such out-of-the-way places as where these siphons were put up.

On the inside ends flat wrought-iron frames are provided, to impart stiffness, and on the outside heavy cast-iron frames are riveted. The gates are of green-heart timber, tongued and grooved, and are hung from a $1\frac{1}{2}$-inch diameter axle by three $4 \times 4 \times \frac{1}{2}$-inch tee-iron hinges—the centre one being carried up to near the level of high water, and by means of a chain can be opened from the top of the embankment. A cast-iron balance weight (about 2 cwt.) is bolted to the back of each gate, since they were not found to close soon enough without same. It is of great importance in tidal gates that they should be so balanced as to remain open until the outside water is practically level with that inside, and the flow ceases; then they should at once close. Various devices have been adopted to effect a satisfactory balance, but the most obvious arrangement is one in which the gate is balanced in such a manner as to admit of ready adjustment from time to time. In the present case this can be readily effected—first, by removing the loading, and afterwards by adding counterpoise weights to the projecting T iron placed at the centre of width of each gate. To admit of access to the interior, strong cast-iron man-doors are rivetted to the top of each siphon, as shown, having a clear opening of 17 inches diameter. These are provided with faced covers bolted down, and with wooden plug in centre, so that the flow of water may be at once arrested in case of emergency by admitting air. Branches are cast to the sides of the mandoor seats, for the connexions to the air pump.

The siphons were erected between two of the old sluices, and in a part of the embankment of the section shown on the plate, and were placed with a space of eight feet between them, in which the small house and air pump were fixed,

on the top of the embankment. The level of the top of the embankment is six feet above high water spring tides, and the siphons are bedded four feet below the surface at this part, so there is a clear height of two feet to prevent passage of water from leakage, from imperfect staunching under the tubes. As the tubes drop to the water on either side, their direction gradually protrudes from the embankment, until at low water-level they rise altogether out of it, and thereby do not require any dangerous removal of the old work; this was a most desirable condition to fulfil, and avoided any necessity for damming. The air pump for exhausting the tubes when starting the siphons is of small power, and has been found amply sufficient for the purpose: it consists of a single-acting cast-iron working barrel, 6 inches diameter and 14 inches stroke, and can be worked by one man. The plunger is of brass, and packed with twisted flax; the arrangement of crank, shaft, connecting rod, standards, and fly-wheel with handle, will be gathered from the plate. The valves (of which there are two, inlet and outlet) are discs of India-rubber, and arranged so as to leave the smallest possible space between them, and as very little clearance is given to the plunger at the bottom end of the stroke, a minimum volume of air remains in the pump at the termination of each discharge. This is an important point in arranging air pumps, and avoids the loss of effect due to the subsequent expansion of the air remaining in the barrel, upon the commencement of the inlet stroke. From the under side of the air pump suction valve, two wrought-iron pipes one inch bore run to the mandoor seats at the top of the siphons, and are connected to same with brass cocks and India-rubber check valves, so that air can be drawn from either or from both siphons at the same time.

The exposed nature of the site, and difficulty of transit, required some care in the erection of the work. This was,

however, considerably facilitated by the tubes being at first made in sections. These, together with the other materials, were shipped on board a small vessel, and despatched direct from Messrs. Grendon and Co.'s works to the face of the embankment: and after some little trouble (owing to the loose stones deposited there) the whole of the material was safely landed on the embankment, and operations commenced by rivetting up some three or four of the sections; after removing the surface where necessary, these were laid in position and the puddle well rammed up underneath. The rest of the work continued in this manner until the siphon was completed, when the second one was started in the same way. Beyond the delays caused by severity of weather, no interruption took place, and the work was completed without the least injury to the embankment. The pitching, where removed, was carefully reset, and brought up close to the iron work. The iron work was painted in two coats best red-lead paint before being forwarded, and received a third coat when completed.

When starting the siphons, about two hours' pumping sufficed to remove the air and cause the water to flow. Upon reference to the plate, it will be noticed that on the inside the ends of the tubes are nearly level, and look in the direction of the line of the tubes. At this point a quantity of loose stones and some earthwork were drawn upwards and discharged through the siphon with the water until a cavity of the extent shown was cleared away; this was accompanied with such noise and apparent violence by the stones coming in contact with the stays situated between the flat sides of the tubes that it was feared some injury might have been caused; however, a careful examination, did not show any. The extent of the cavity thus formed at the inlet is of a comparatively small nature, and is in no way calculated to injure the stability of the embankment.

The author is indebted to Mr. M. J. Farrell for some few particulars of the working of the siphons since their erection. The number of hours worked upon each tide depends upon the flood-level inside, the maximum height of which is about 3 ft. 6 in. over low water-level of spring tides; and when this is the case, the siphons run about seven hours upon each tide (ebb and flow) on low springs in calm weather. From one to two inches difference in level is sufficient to cause the water to run in moderate weather, and the gates close when the outside level of water is practically the same as that on the inside. No pumping is practically necessary, and although it is usual to work the air pump for about ten minutes on each spring, *i.e.*, say once a fortnight, the author believes if even this were discontinued the regular flow would not be affected; indeed, when the siphons were first set to work a period of six weeks was passed over without once working the pump; and then upon trial, a few strokes were sufficient to exhaust the tubes. A short time before the siphons start to work on each tide, there is always a little air in the top of the tubes, probably due to small leakage, and the abstraction of air from the contained water during the period of inaction; but this is very soon swept out after a few minutes' work, and when the gates close, with the rising level of water outside, a stroke or two of the pump will draw up water In the summer of 1869, the inside level of the water being low, and after the siphons had been at work some months, the author noticed a continuous stream of air drawn through the tubes, entering by small whirlpools close to the entrance end, while on the outside could be seen by the broken state of the water it was readily cleared out by the current. The author has been careful to give every information upon this matter of pumping the air from the tubes, since it was at first feared that the satisfactory working of the siphons would be greatly interfered with thereby. At the same time, it must be

mentioned that Mr. Stoney's anticipations as to the absence of inconvenience from this cause have been fully realized.

It is difficult to give any exact particulars of the quantity of water discharged, owing to the defective state of the surrounding catchment drain, but Mr. Farrell considers about two inches over an area of 2,200 statute acres is the maximum result, from a ten hours' run, and, say, with a maximum difference of level of 3 ft. 6 in.; this, of course, would be the work of two tides or two periods of five hours' consecutive work, five hours being the average working period for each tide, and would show a quantity discharged equal to about 445,000 tons. Mr. Anderson shows the net daily average quantity to be drained, as due to rainfall alone, to be 20,862 tons per day, but the defective state of the catchment drain causes such a considerable leakage as to greatly increase this quantity.

Since the year 1870, the pumping engine, described in Mr. Anderson's paper, has been worked, and the water is kept below the limits of action of the siphons in the summer, so that they now only come into operation during the heavy winter floods. When first started, they performed most important duty in clearing away the accumulated water due to the previous unsatisfactory condition of the three sluices.

The closing up of the old sluice was accomplished by throwing down loose stones at each end, and forming a rough coffer dam by adding clay behind same; then by cutting down the embankment, the timber frame-work and lining of the sluices were removed, and the space closed up with clay, and the whole made good again.

No appreciable wear has been noticed in the siphons, and the plating appears to be amply strong for the work, and is kept in very good order by being cleaned and tarred once during the summer of each year.

The applicability of siphons in all cases of impounded water is of course limited to a height of some 20 to 25 feet, and it would probably be found at this height that the difficulty of keeping the tubes charged with water would be considerable; but there can be no doubt that in such cases as that met with in the Wexford Reclamation no better plan could be adopted, and the safety of such embankments would be vastly increased by the entire prevention of the injurious influence of leakage between the structure of the sluices and the material forming the embankment.

[10th December, 1873.]

ROBERT MANNING, Member of Council, in the Chair.

On the DISCHARGE *of* TIDAL SLUICES. By CHARLES P. COTTON, President.

IN the fourth volume of the Transactions of this Institution will be found a paper by Mr. Terence Smith on self-acting sluice doors, having particular reference to, and detailed description of, the doors of the sluices at Ballyteigue, in the County of Wexford.

The essential feature of the design of these sluices was, that the door was to be always either fully open or quite shut, no permanent intermediate position being possible.

To accomplish this it was necessary to make the doors of such materials and in such proportions that the whole should be of the same density as sea water, and secondly, it was necessary that the sluice should be laid *entirely* below low water of spring tides, so that to the very last moment of slack water the door should be able to float in a horizontal position.

This may be termed a perfect door for a tidal sluice.

Of course the trouble of laying the work so low as several feet below the lowest springs must be considerable, and it might at first sight appear that the gain may not be correspondingly great. Every case must, of course, be treated by itself, but to all are these two things common, first, that for the last foot of ebb, and first of flood, the acting head is the greatest, and second, that the time available for discharge under this maximum head, namely, that occupied by the subsidence of the Ebb through the last foot (or unit of height), and the rise of the Flood through the same, is far greater than the time of the variation of the tide through an equal space at any other period until high water is approached.

For instance, take a 12-feet range of tide. In this case the

tide will subside from the half-range or mean level through one foot in 19 minutes, while 71 minutes will be occupied by its subsidence through the last foot of the ebb.

It need hardly be remarked that the fact of the sluice being submerged has no effect on the discharge, provided the channel outwards be clear.

Having had occasion to refer to Mr. Smith's paper, the author naturally expected to find it followed up by some investigation into the duty of the sluice, and its superiority over an ordinary one; but if such an investigation were made at the time the results were not published.

On referring to the standard works on hydraulics, several cases will be found of discharge under heads varying according to different laws, reduced to simple formulæ; but nowhere can I find any attempt so to deal with a head varying according to the action of the tide.

Again, the effects of many kinds of obstructions, angles, bends, &c., are given, and formulæ for them deduced from experiments, but no such investigations have been made by which we might learn the effect on the discharge of a sluice by its flap being constructed of a solid cast-iron plate, "a construction," as Mr. Smith well expresses it, "which could originate only in the most total disregard of self-action."

The subject therefore may be divided under two heads:—

1. The discharge during a tide, supposing the sluice to be perfect.

2. The effect on the discharge of the doors being variously placed as to height, and being formed of different materials.

The first is the subject of this paper.

The case which it is proposed to examine now is that of a tract of land reclaimed from the sea by an embankment which has in it, or rather under it, a sluice with a *perfect* door. It will be assumed that the reservoir, or ponding space, for the accumulation of drainage water and rainfall is sufficiently

large to prevent any appreciable alteration in its level during the time the sluice is open.

Let A denote the cross section of the sluice.

D the duration of a tide (about $6^{h.}\ 12^{m.}$)

R the semirange of a tide.

H the height of the reservoir surface over low water.

T the time the tide takes in receding from the height H to low water.

h the height at the time (t), both measured or counted from low water.

Q the quantity discharged.

f the factor of the sluice, *i.e.*, the ratio of the actual to the theoretical discharge. This factor is determined by experiment for the particular class of sluice, being a function of the shape and position of orifice, of the approaches, &c. It must be borne in mind that this factor for *each case* is not indeterminate, but *well known*.

The quantity discharged during the small portion of time dt is:—

$$d\,Q = f\,A\sqrt{2g}\sqrt{H-h}\,dt. \qquad (1)$$

and the integral of this expression between the limits of any two values of h or of t will be the value of Q between those limits.

The first step is to ascertain the relation between h and t so as to eliminate one of them, or to substitute a third variable for them both.

This relation is expressed as follows:—"If you represent by the vertical diameter the total range of the tide, then the times taken by the sea in rising to different points on that diameter are represented by the lengths of the arcs of the circumference comprised between the origin and horizontal lines drawn through the corresponding points of the diameter, so that the semi-circumference will represent the total time elapsing between high and low water."*

* Minard—"Ouvrages hydrauliques des ports de mer," p. 5.

This it will be seen at once is expressed by—

$$h = \mathrm{R}\left(1 - \cos 180^\circ \frac{t}{\mathrm{D}}\right)$$

in which $180^\circ \frac{t}{\mathrm{D}}$ is the angle θ in the figure. Plate II., Fig. 1.

Expressing h, t, and dt in terms of $\frac{\theta}{2}$ the discharge between $h = \mathrm{H}$ and $h = 0$, that is from the moment when the sluice begins to act till low water is given by the equation.

$$\mathrm{Q} = 2\, f\, \mathrm{A} \sqrt{2g}\, \frac{\mathrm{D}}{\pi} \int \sqrt{\mathrm{H} - 2\,\mathrm{R} \sin.^2 \frac{\theta}{2}}\, d\, \frac{\theta}{2} \qquad (2)$$

This is not *directly* integrable, but taken between the limits of $\theta = 0$ and $\theta =$ the angle corresponding to H, it so happens that the portion under the integral represents the difference between a hyperbolic quadrant and its asymptote, the semiaxis being equal to $\sqrt{\mathrm{H}}$, and focal distance from centre equal to $\sqrt{2\mathrm{R}}$.

Hence the value of the integral can be got by an easy graphic method. Plate II., Fig. 1.

Make $\mathrm{AB} = \sqrt{\mathrm{H}}$ and $\mathrm{AC} = \sqrt{2\mathrm{R}}$. Construct the hyperbola by drawing a series of lines to the circle D B from C, and, where each meets the circle, drawing a perpendicular. These perpendiculars envelop the hyperbola. The next step, is to draw a parallel to the asymptote, cutting the curve as far from B as the limit of the drawing will permit. Then, with a compass, step from B to E and *back* to E G. Draw A F perpendicular to E G, and F G (measured by scale) is the value of the integral. This multiplied by the constants, as above, gives the discharge during the ebb, which must be doubled to get the entire discharge during 12 h. 24 m.

The discharge is usually got by dividing the *time* of the sluice's action into a number of equal parts, ascertaining the acting head due to each and adding up the $\Sigma\sqrt{\mathrm{h}}$.

As examples of the two methods, the author has taken out the discharges under the ranges and heads given in the following table, in both ways, having used for the graphic method a scale of two inches to one foot.

R	H	T	Discharge by Graphic Method	Discharge by Calculation	$\Sigma h\sqrt{h} \div T\sqrt{H}$
Feet	Feet	Minutes	Cubic Feet	Cubic Feet	
10	14	235	198,201	197,973	·748
10	13	222	182,571	180,798	·753
10	12	210	167,298	165,018	·757
10	11	198	151,314	149,778	·759
10	10	186	135,684	134,733	·763
10	9	174	120,411	118,248	·766
10	8	162	106,206	105,894	·770
10	7	150	92,352	91,908	·773
10	6	137	78,855	78,177	·775
10	5	124	65,712	64,614	·777
10	4	110	*50,439	51,321	·779
10	3	94	38,718	38,223	·781
10	2	76	26,640	25,310	·783
10	1	53	12,786	12,570	·785
7	6	169	94,490	95,298	·767
7	4	136	62,166	62,136	·775
7	1	64	15,275	14,902	·775
3	3	186	71,078	70,882	·778

* There was clearly an error here; it is left uncorrected to show the practical margin of error.

In each case the aperture is taken as one square foot, and the factor as 300.* These quantities do not, however, affect the general question.

Several interesting results appear from these figures, besides the confirmation of the graphic method.

In the first place, the result by the graphic method is in excess of the other, as, of course, ought to be the case. There are two apparent exceptions to this, the result, no doubt, of errors. The author has preferred to leave them as they were worked out, showing what margin of error may be expected in practice.

Again, the compound relations of heads and times of acting are so intricate that a 3-feet semi-range acting with a 3-feet head, discharges nearly twice as much as the same head with a 10-feet semi-range.

But the most important deduction is that given by the figures in the last column. In this column, under the head $\Sigma t\sqrt{h} \div T\sqrt{H}$, we have, as will be seen at once, the factor, which if applied to the discharge, calculated as for the whole time T, with the maximum head H, will give the actual discharge under the varying head.

It will be seen that the limits within which this factor varies are small, from ·75 to ·79. I have not considered it necessary to go into cases where the height is more than seven-tenths of the *whole* range of tide, as such cases can hardly arise in practice; but I may point out the minimum value of the factor, which is when $H = 2\ R$. In this case the asymptote and quadrant of the hyperbola, both merge in the axis, and consequently the difference between them is equal to $\sqrt{H}$, and the discharge is

$$Q = f\ A\ \sqrt{2g}.\ D\ \frac{2}{\pi}\sqrt{H}$$

The factor is then, of course, equal to $\frac{2}{\pi} = \cdot 6366$,

* Beardwood—"Manual of Hydrology," 1862, p. 3.

which I have verified by calculation, resulting in a factor of ·633, which is, as might have been anticipated, slightly under the true one.

The rule may, therefore, be laid down that the discharge of a tidal sluice in perfect order, and constructed in the best way, is seven-ninths of what the discharge would be if the maximum head were acting all through, that is, for the time which elapses between the Ebb receding below the level of the interior reservoir and the Flood rising to the same height.

$$Q = \frac{7}{9} f A \sqrt{2 G} T \sqrt{H}. \qquad (3)$$

Any irregularity arising from the variation of the factor, thus expressed, from the true one, will be swallowed up in the unavoidable irregularities attending all cases such as the discharge of sluices.

One thing is manifest, namely, the importance of securing the perfect action of a tidal sluice during the last period of the Ebb and the first of the Flood.

The author is indebted to B. Williamson, Esq., F.T.C.D., for the suggestion of the hyperbola, used in this paper.

The time of employing the graphic method is not one-fourth of that taken up by the calculations.

[14th January, 1874.]

CHARLES P. COTTON, President, in the Chair.

On the FAILURE *of the* BEACON *on the* ALDERN *or* ALDERMAN ROCKS *in* CROOKHAVEN BAY *in the year* 1865. By the PRESIDENT.

THE records of failures of structures are always of the greatest use if sufficiently precise and detailed. It may be that a warning is thus given of a source of danger hitherto totally unsuspected, or, as in the case of this beacon, some practical information is afforded by what is observed during the failure that could only otherwise be matter of surmise.

The author in using the word "failure" does not infer any want of skill or care in the design or execution of the work. As a matter of fact the work of this beacon was done in the most excellent manner.

As regards records of failures, *no* record of the failure of an engineering structure can be without its value, provided it states as facts only what are really so, as it must afford, perhaps by itself, perhaps in conjunction with other records, some data on which the application of theory to practice may be brought a step nearer to perfection.

With regard to the application of theory to practice, it is sometimes not sufficiently borne in mind that the real value of theoretical knowledge to our profession is that it teaches us how to manipulate the data which we accumulate from experiments and experience. As then the value of theory is to a great extent dependent on the number and accuracy of the experiments and practical observations by which it is

rendered available, records of facts accomplished, successes or failures, are always valuable, and should be acceptable subjects for papers in this Institution.

At the extreme south-west corner of Ireland lies the Harbour of Crookhaven. The mouth of the harbour faces the east, and is about half a mile wide between Rock Island on the north and the Aldern Rocks on the south.

The rocks consist of a kind of slate, very much broken and shattered; the strike being nearly east and west (true) and the dip 80° south, they have assumed the shape of long ridges, running out in an easterly direction. On the extremity of one of these spurs the beacon was placed.

The design was that of a cast-iron casing, bolted to the rock, and filled with masonry, in cement, the whole being surmounted by a mast, carrying a large cast-iron octohedron.

In shape it was the one-half of a circular spindle. The height being 31 feet 6 inches to where the curved sides would meet, and the diameter of the base 9 feet, it follows that the radius of the generating circle was 110 feet.

The casing was composed of cast-iron plates of varying thicknesses, from $1\frac{1}{4}$ inches to $\frac{3}{8}$ths of an inch.

Each plate was 6 feet in height, and formed exactly one-ninth of the surface of the tier in which it was placed. Round the edge of each plate, and horizontally across its middle there were deep strengthening flanges, by which the plates were bolted up together. The bottom tier of plates was furnished with a broad base flange, through which passed eighteen holding-down bolts $1\frac{1}{4}$ inches square, and sunk about 5 feet into the rock.

The hearting was of stone, laid in cement mortar. This was carried to a height of 24 feet 6 inches, and capped by a strong cast-iron plate, in which the mast was stepped.

The mast was of wrought-iron, $2\frac{1}{2}$ inches in diameter, and 15 feet 6 inches long, of which 6 feet projected above the spindle,

and was surmounted, as before mentioned, by an octohedron of cast-iron. This octohedron was originally designed to be of light wrought-iron, instead of a very heavy casting.

The beacon was furnished with a refuge ladder and gallery.

One evening in April, 1865, the beacon was seen to be all right, but the next morning it was found to have heeled over to the north, at an angle of between twenty and thirty degrees from the vertical.

On examination it was found that it had turned on the bottom edge of one of the lower plates, and had drawn up nearly all the holding-down bolts.

In this position, it having been painted white, it was mistaken by a friend of the author for a yacht entering the harbour.

It thus remained without alteration until November in the same year, when, as it was being taken to pieces, it heeled over and sank in deep water.

The first point to be observed is that the edge of the plate on which it turned was quite uninjured, showing that in estimating its stability, or that of a similar structure, the moment of resistance to heeling over may be taken as the weight multiplied by the full half base without any qualifying factor of safety.

The second is that the holding down bolts were useless as constituting a portion of the strength of the beacon. Indeed their sole duty was to secure the lower portion of the casings during erection. In such a position as this, where the rock is only dry for a very short period of each tide, the fitting of these bolts, no matter what care is taken, can never be perfectly done. The consequence is that, in case of the beacon having to resist a shock, the strain comes on only one or two at first, and they are all thus conquered in detail.

Weight is the mainstay of these works, and, except in

cases where the necessity of the structure interferes, should be looked to as the chief source of stability.*

The author has had the quantities, weights, &c., of this beacon very carefully taken out, involving some rather nice calculations, and he finds the data on which the stability of the beacon may be considered are—

Weight of masonry, - - -	65·5 tons.
Weight of iron, - - - -	13·7 tons.
Total weight of beacon, - - -	79·2 tons.

Height of centre of gravity over base, 9·469 feet.

Hence we know that the moment of resistance to overturning was at least 356·4 feet tons.

One consideration in the present case convinces the author that this beacon succumbed to no ordinary sea; it is this—On the morning when it was first seen to have been damaged it was in such a position that the centre of gravity was nearly, if not quite, vertically over the fulcrum on which it had turned. It cannot be conceived that a wave or succession of waves having effected so much of the overturning would not have *completed* it. It may be conjectured that the failure must have resulted from a heavy sea, combined with a shock from some floating wreck of some kind that caught it high up, bending the projecting six feet of the mast as shown on the drawing. Should this have been so, the blow would have been given and passed, and then its remaining held by the few of the holding-down bolts that then came into play can be understood.

The author makes two suggestions arising from this failure. First, with regard to the holding-down bolts.

It is quite clear that if one bolt can be secured in the centre of the base, whose sectional area is equal to the collective area

* See "Stevenson's Account of the Skerryvore Lighthouse," pp. 50 *et seq.*

of those all round the base, the same duty will be done by it as by the 18 separate ones, as the product of any number of areas multiplied by the distances of their several centres of gravity from a plane is equal to the collective area multiplied by the distance of the common centre of gravity.

The author thinks a more efficient plan would be to secure a bolt whose sectional area would be 28 inches in the centre of the base, and thus get the *full* value of its assistance against overturning.

And further, in many instances, of which the Aldern Rocks beacon was one, where the danger comes only from one side, advantage might be taken of this to place the holding-down bolt excentrically, and get still further duty out of it.

Many ways of designing this will occur to every one.

The second suggestion is one which might be practically carried out in such structures with great advantage.

In the south and west of Ireland there is a ready supply of a rock, sulphate of barytes, in appearance resembling statuary marble, but with the important quality that its density is 4·4.

Now, for works where weight is of great importance, such as this beacon, the filling might be made with a concrete of this barytic stone and Portland cement.

The weight of this concrete is estimated at 252 lbs. per cubic foot, which exceeds the weight of masonry filling in the ratio 5 to 3 in air, and in sea water, when both are immersed, the relative weights will be 184 lbs. and 96 lbs. per cubic foot respectively, or in a ratio of very nearly 2 to 1.

The weight of this beacon, if filled with barytic concrete, would have been 113 tons instead of 79 tons.

The cost of such a concrete would be not more than masonry, and might be much less, as a large amount of the mineral is raised and abandoned as unfit for manufacturing purposes, owing to impurities, which would no way affect its utility for the purpose of forming concrete.

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There are many other purposes for which such a heavy filling will no doubt be advantageous—they will suggest themselves to all—but for such service as this beacon it is pre-eminently adapted.

The author's idea of barytic concrete has been communicated to some of the highest authorities on sea works, and it has been very favourably received.

The importance of gaining additional weight without increasing the surface to be exposed is admitted on all hands, and if once introduced into practice in a single instance it would become universal where the price of the material would admit; and as to this, in no works is an increase in expenditure so readily sanctioned, and deservedly so, as in lighthouses and beacons, where there is any certain additional security to the work or advantage to the public to be gained by it.

It has been suggested that the iron casing might be dispensed with altogether if the barytes can be procured of sufficient hardness for building it of "concrete rubble," *i.e.*, with small stones and Portland cement. Two beacons have lately been built in this way by the Board of Northern Lights in very exposed situations. Mr. Thomas Stevenson has proposed to adopt this plan for building lighthouses. (See "Nature," September, 1871).

There can be no chemical action whatever between the barytes and the cement or the iron, nor, if the barytes could be obtained fit for building, would there be any weathering.

[February 11th, 1874.]

CHARLES P. COTTON, President,
In the Chair.

The following Candidates were ballotted for and duly elected:—

FOLLIOTT BARTON, JOHN H. BRETT, CHARLES R. GALWEY, JOHN J. F. GREENE, JOHN LONGFIELD, ROBINSON SOUTTAR, as Members; THOMAS J. DIXON, NATHANIEL L. FALKINER, as Associates.

The President then delivered his Address as follows:—

GENTLEMEN,

My first duty is to return to you, fellow-members, my thanks for the honour which you conferred on me when you elected me to fill the chair of this Institution, a dignity of which I may well be proud when I look at the names of those who have preceded me.

From the foundation of the Institution in 1835 until the year 1858 it was not customary for any Presidential Address to be delivered. Since then your Presidents have each performed the duty which is before me to-night.

As may naturally be supposed, I have studied these addresses that I might avoid repetition, and not take up any speciality which has already been dealt with by abler hands.

The history of Engineering in Ireland has been most fully given by the late Mr. Mullins up to the date of his address, May, 1860. Without attempting to continue it with the same detail, I may glance at some of the principal engineering works carried out in Ireland since that date.

In railways, though a very large additional mileage has been added since 1860, with the exception of the line from Athlone to Westport and Ballina, and the extension from Wicklow to Wexford, which are really new trunk lines opening up the Counties of Mayo and Wexford, the additions consist of small branches and extensions to the main lines. The total mileage now completed and open is 2,066 miles.

Considerable attention of late years has been turned to the narrow-gauge system of railway, typified in the Festiniog Railway, so well described by Captain Tyler in the 24th volume of the Transactions of the Institution of Civil Engineers.

This little line, on a 2-feet gauge, is a marvellous success, but in introducing it into any argument about the gauges, it should be remembered that it was not *designed* as a light *locomotive railway*. It was originally a mineral *tramway* for the conveyance of one peculiar class of material—slates—which form a very heavy load in a small compass; hence the narrow gauge originally determined on.

It is not correct to take, as is usually done, the narrowness of gauge as a direct index of cheapness of construction. It influences it, no doubt, to a great extent in the cost of permanent way, bridges, and rolling stock, and to an extent in the cost of earthworks, which depends on the nature of the country, the saving being very small in an open easy country, and large in a mountainous district, where the works may be reduced by very sharp curves. On the latter point, however, I am certainly of opinion that we shall see very much sharper curves introduced in time into the wide-gauge system. Not

many years ago half a mile was the minimum radius of curves in general practice, and the ruling gradient 1 in 100; but the exigency of the case in various instances has compelled the adoption of far different curves and gradients, so that we now find a curve of 6 chains on an incline of 1 in 40, which would formerly have been pronounced quite impracticable, and in another instance, what I think still more remarkable, an S curve reversing without any straight, the curves being $7\frac{1}{2}$ chains radius, and so situated that no super elevation can be given to the outer rail. Hence, I think, too much importance is given to the influence of narrowness of gauge on economy of works.

The narrow-gauge system is being introduced among us, on a railway in the north—Ballymena to Cushendall—which it is expected will be opened for traffic in a few months, and in the west on the Ennis and West Clare Railway. Both these are instances of independent railways, not branches. The question of the narrow gauge has been often discussed, and I will not now go into it further than to express my conviction that time will show it is only suited for independent lines, whose traffic, be it goods or passengers, is local, and not carried for transhipment at the end of a broad-gauge line; and that for all branches the system to be adopted where the traffic is small, and it is a question of a *cheap* railway or *no* railway, the right plan will be found to be that of light permanent way on the ordinary gauge.

In the discussion on Mr. Thornton's paper on the gauge of the State railways of India, read before the Institution of Civil Engineers, I find an example of this class of railway on a branch of the Great Western to Brixham, and another, the details of which were brought before you by Professor Downing, a branch from Quainton Road station to Wotton, the seat of the Duke of Buckingham.

Sir Charles Fox, when consulted about the gauge of the

Indian Tramway, wrote a long report, in which he advised that the Company's lines should not be made tramways, but light railways, the load on each pair of driving wheels being limited to the greatest load that could by possibility come upon any pair of wheels in a train. All the rolling stock of the parent lines, except the locomotives, might with safety be carried on rails of not more than 35 lbs. to the yard. Sir Charles Fox recommended a narrow gauge of 3 feet 6 inches for Queensland, but he expressly said that were it not for the sharp curves required, he would not have done so, and it must be noted that there were no existing railways in the country at the time.

It is not, perhaps, generally known that there is a special Act of Parliament empowering the Board of Trade, after having inquired into the circumstances, to sanction the opening of light railways for passenger traffic.

In an easy country, such as the interior of Ireland is, the saving of a 2-feet gauge line over one of the ordinary gauge laid with light rails, at the outside would not amount to £500 a mile.

A great deal of the activity now apparent amongst the Irish railways is due to the competition of the great English Companies for the Irish traffic. We find the London and North Western constructing a harbour at Greenore, subscribing to the cost of the Phœnix Park Railway, and lending a large sum of money to the Dublin, Wicklow, and Wexford Railway. Again, we have the Waterford and Limerick Railway, with its ramifications to Tuam, Killaloe, Foynes, Newcastle, and, before long, Tralee, in alliance with the Great Western. Two years ago the latter company got powers to run steamers to Waterford, and were only refused similar powers to run to the new harbour at Rosslare, because the harbour was not then constructed. When it is, and a sea passage from the south of Ireland to the

south of England, shorter than that from Kingstown to Holyhead, is established, a very keen competition may be expected.

Since the year 1866 there has been but little done in the way of the promotion of new railway schemes, but there now appears to be something of a reaction.

One thing that possibly may conduce to this is the fact of the purchase by Government of Irish Railways being definitely declined. As long as that question was in suspense it could not be expected that capital would be embarked in new railways.

The number of Bills lodged for the ensuing Session of Parliament was 281, of which 33 related to Ireland, 22 of them being for the construction of new works.

Two Irish Bills have been lodged for the reclamation of slobs from the sea—a kind of enterprise to which the attention of capitalists is not at all sufficiently turned. You are all, doubtless, aware of places where such reclamations would be easy and remunerative. In many of what would be the easiest and best, an insuperable objection arises on the part of the Marine Department of the Board of Trade, who jealously guard the backwater if in any way affecting the navigation; though they have in some instances, as at Wexford, allowed the reclamation of thousands of acres inside the harbour's mouth.

Many years ago a company was projected to undertake reclamations in various places in Ireland, and estimates were prepared for Mr. Dargan, by Mr. Le Fanu, of the cost of reclaiming the following, among other slobs:—Castlemaine, Poulnasherry, Querrin, Clonderlaw, Tarbert, Dungarvan, Youghal, Barrow. The estimated cost varied in the different reclamations, and sometimes in different parts of the same reclamation, the highest being £57 per acre of reclaimed land, and the lowest £12 8s. per acre.

An attempt was made, and the greater portion of the

works completed, to reclaim Poulnasherry slob, but the bank has never been closed. This bank was intended also to carry the Kilrush and Kilkee Railway.

In addition to the Bills I have mentioned as having been lodged relating to Ireland, notice has been given that it is intended to apply for an Act to empower the Commissioners of Public Works in Ireland, to remove obstructions in the River Shannon, to prevent floods, and remove flood waters, and for other purposes.

The uncertainty arising from the price of labour, and that of the price of materials, combine at present to cause a large difference sometimes between estimates and tenders. Several men tendering for the same work may be all equally good and experienced contractors, but the tenders will show discrepancies arising from the different margins put on to cover alterations in price of labour and materials.

The following list of prices paid to each labourer per day on Mr. Dargan's and Mr. Thomas Edwards' works, from 1830 to 1874, is well worth recording:—

		s.	*d.*
1830–32	Kilbeggan Canal - - -	1	2
1832–34	Kingstown Railway - - -	1	6
1834–39	Ulster Canal - - - -	1	4
1839–42	Ulster Railway - - - -	1	4
1841–43	Dublin and Drogheda Railway - -	1	4
1844–50	Great Southern and Western Railway -	1	4
1849–50	Midland Great Western Railway -	1	4
1850–51	Same - - - - -	1	6
1851–52	Same - - - - -	1	8
1852–53	Mallow and Killarney - - -	1	8
1853–54	Portarlington and Tullamore - -	1	8
1854–56	Mullingar and Cavan - - -	1	10
1854–58	Limerick and Foynes - - -	1	8
1855–59	Banbridge and Scarva - - -	1	8
1856–58	Monaghan and Armagh - - -	1	10
1856–58	Ballymena and Portrush -	1	8

		s.	d.
1857–59	Tullamore and Athlone - - -	1	10
1857–59	Limerick and Ennis - - -	1	10
1858–60	Mallow and Fermoy - - -	1	10
1860–66	Dublin, Wicklow, and Wexford - -	1	10
1873	Same - - - -	2	4

These figures show that while in 1830 the price of labour on contract work was 7s. per week, it rose soon to 8s., where it remained until the year 1850, rising to 10s. in 1854, 11s. in 1859, and now to 14s. per week.

These are all in country places. It should be noted that the prices given on railway contracts always exceed that of the neighbouring country, owing to the work being harder and the weekly sum liable to be considerably reduced for wet days or parts of a day.

Railways in Dublin.

It may be interesting to give a short *resumé* of the various projects which have been, from time to time, put forward for the purpose of uniting the different railways which have termini in Dublin.

The idea first originated with the eminent engineer, Charles Vignoles, whom we number with pride among our Past Presidents.

So long ago as 1837 Mr. Vignoles proposed to connect Westland-row Station with the then contemplated terminus of the "Cork Main Line," at Barrack-bridge.

Mr. Vignoles' plan may be briefly described as that of a railway supported on girders on the top of a double row of handsome stone columns, one row being at the edge of the curbing of the footway along the South Quays, the other row being in the river. This colonnade continued until Carlisle-bridge was nearly reached, when the line would have crossed over Westmoreland-street by a bridge, and gone on then to Westland-row.

Mr. Vignoles contemplated no junction with the Northern

Lines, and the Midland Great Western was not then proposed. His principal, if not sole object was to connect Kingstown Harbour with the middle and centre of Ireland, for the speedy transit of mails and passengers.

I should not omit to mention that combined with this railway project was a plan by which the foundations of the river pillars were to form a catch-drain sewer for the entire of the south side of Dublin, from Kingsbridge to Carlisle-bridge.

With few exceptions, this direct connexion between Kings-bridge and Westland row has been the guiding star to all the engineers who have since presented the public with their respective schemes.

No attempt was made after this, as far as I know, to bring forward the idea of a Junction Railway in Dublin until 1859, when it was taken up by Mr. W. R. Le Fanu, with the concurrent assistance of all the traffic managers of the different railways. The plan then sketched out was to unite all the lines by a railway starting from the mouth of the Dodder, and in connexion by means of tramways with the South Quays, crossing and connecting with the Kingstown Railway near Sydney-parade, crossing the Wicklow Railway at Major Sirr's Avenue, and thence running through Rathgar to the Great Southern and Western, and on to the Midland by a route almost identical with the Park Line now *being* made, thence by the side of the Royal Canal, where the Liffey Branch *is* now made, picking up the Drogheda Railway, and terminating in a very large goods station at the North Wall.

It is remarkable how Mr. Le Fanu's plan has been and is now being carried out in detail. The first portion was nearly identical with the Kingstown Connecting Railway from Sydney-parade to Ranelagh, afterwards legalized but abandoned; and the latter, almost the same as the Liffey branch of the Midland Great Western and the line now being

carried out by the Great Southern and Western. I have little doubt that in time we shall see the connexion from Ranelagh to Kingsbridge also executed.

Shortly after this Mr. Blakiston proposed a plan, which practically, to a great extent, would have replaced the Grand Canal within the suburbs by a railway.

Nothing further was done until, in November, 1862, Mr. Barry startled the Corporation with his Dublin Metropolitan Railway, with high-level crossings over Westmoreland-street, D'Olier-street, and the River Liffey below Carlisle-bridge.

No connexion with the Midland Railway was proposed, but its obvious feasibility was pointed out in Committee.

Mr. Barry having abandoned a portion of his plan to get rid of the opposition of the Port authorities, carried his Bill before the Lords, in spite of the opposition of the Corporation, but subsequently abandoned it.

Mr. Hemans, in Committee, proposed a circular connexion with a central station in Rutland-square, and Mr. Le Fanu now first brought out the idea of going *under* Westmoreland-street.

In the following year a flood of schemes set in. Mr. Barry brought forward again the Dublin Metropolitan Railway, altered from last year by the addition of a branch to the Midland, and by the adoption of the idea of going under Westmoreland-street.

Mr. Barton designed the Dublin Railway, the principal feature of which was a central station between Dame-street and the River Liffey, at some height over the surface. From this station three lines went westwards—one to Kingsbridge, one to Harcourt-street, and one to Broadstone. No connexion with Westland-row was attempted, but Mr. Barton proposed to take the Kingstown traffic by a connecting line to and through Harcourt-street Terminus.

Mr. Hemans designed the Dublin Grand Junction Railway, which had no central station, but connected all the lines by a

railway running from Ringsend Docks round by the Canal to Kingsbridge, and thence across the Park to the Midland.

Mr. Hassard also brought forward a simple connexion between Kingsbridge and the Midland Railway. This had been previously proposed by Mr. Hemans and Mr. Le Fanu jointly.

The remaining proposition of this year was called the Dublin Trunk Connecting Railway, and was designed by Mr. Mallet, Past President of this Institution, and Mr. Burke.

It, like Mr. Hemans' line, had no central station, and may be called a general railway connexion from the Kingstown Railway at Ringsend "north-abouts," whereas Mr. Hemans' was "south-abouts."

The principal feature of the Trunk Connecting Railway was its tunnel under the Liffey.

As might have been expected, the fight in Parliament was a long and serious one, and ended by the Committee, who had at one stage of the proceedings indicated that a central station was a *sine quâ non*, adopting the Trunk Connecting Railway, to the astonishment of every one in the room; and not the least astonished, I take it, were the promoters of the Trunk Line themselves.

You all know the end of this proposed railway.

At the same time, 1864, an Act was passed for the Rathmines, &c., Railway, Mr. H. Brett, Engineer, which has since remained a dead letter.

In the succeeding session an Act was obtained for the Dublin Metropolitan Junction Railway from Harcourt-street to Kingsbridge, Mr. J. Kincaid, Engineer. This also has remained a dead letter, as has also been the fate of the Kingstown Connecting Branch of the Wicklow Railway from Ranelagh to Sydney-parade, for which an Act was obtained, Cotton and Flemyng, Engineers. I may, of course, be prejudiced in the matter, but I do think this last line contains the elements of a great success.

A proposition was brought forward by my firm in 1868–9 and 1869–70, for a large and commodious low-level station near D'Olier-street, to replace Westland-row, but the shareholders of the Wicklow Company would not sanction its being proceeded with.

In 1870 Mr. Browne, Engineer to the Great Southern and Western, made two propositions for connecting, in Dublin, the Kingsbridge Terminus with the North Wall. The first, a sort of second edition of Mr. Vignoles' plan, was proposed to go along the *north* quays on pillars to the North Wall. This was opposed by the Corporation, and then plans were lodged for the present Park line, but withdrawn subsequently.

In 1871–2 Mr. Browne again lodged plans for the Park line, and Mr. Barry brought forward a new plan, called "The Dublin Central Station Railways."

In this year also an effort at revival was made by the Trunk Connecting Company, who now assumed the new title of Dublin Port and City Railway.

Plans were also lodged by Messrs. Cauley & Newton for the Dublin Central Stations and Railways, but the Bill was not proceeded with.

Mr. Barry's plan, of 1871–2, was to go from Kingsbridge down, under, and along the south quay, emerging and rising to a central station covering the river between Essex-bridge and Carlisle-bridge, with under-ground branches on the north to the Drogheda Railway, and on the south to the Kingstown Railway.

Of these Mr. Browne's line alone was sanctioned.

Again, in 1872–3, Mr. Barry came forward with a central railway project, not unlike his proposal of 1864–5. This bill was not proceeded with.

In 1872 the Wicklow Railway Directors offered their Board-room for the exhibition of such designs for connecting railways in Dublin as might be submitted to them. In response the walls were adorned with several plans, one by Mr. Barry,

embodying a new feature of an underground connexion between Westland-row and the authorized Trinity-street Terminus of the Rathmines Railway.

There was also a plan proposed by Mr. John Edwards for a connexion between Kingsbridge and Westland-row, and a branch down to the end of the south wall.

Among the plans was one which my firm had submitted to the Wicklow Board for the D'Olier-street extension, with a slight alteration in levels, so as to allow of its being carried on over the river to Amiens-street.

Mr. Barton sent a plan identical with mine.

Mr. J. Chaloner Smith submitted a plan not unlike mine as to its course, but differing in this, that Mr. Smith proposed to put the station over the River Liffey.

A plan was also proposed by Mr. Price, adopting the low-level D'Olier-street station, with a branch going eastwards, under and across the river, to the Drogheda Railway.

In this year also a most comprehensive scheme was proposed by Mr. Stoney, Past President, but it was never publicly announced.

This year Mr. Barry again lodged plans, which I have not seen, but which I understand may be described as a line joining Kingsbridge and Westland-row with a central station, and a line from near Milltown Station, on the Dublin, Wicklow, and Wexford Railway, to the Kingstown Railway, near Lansdowne-road Station.

The deposit for this Bill has not been lodged, and it consequently lapses.

In all there have been 26 elaborated plans for joining the railways, which have their termini in Dublin.

Harbours. Among the principal Engineering works of late years in Ireland stand out the railway and harbour of Greenore, carried out by Mr. Barton, and the improvements to the harbour and River Liffey in Dublin by Mr. Stoney, and the

construction of the Spencer Dock by Mr. Price—works, I am proud to say, redounding to the credit of members of this Institution.

The harbour of Greenore, opened by the Lord Lieutenant on the 30th April, 1873, affords a safe anchorage ground of 1,200 to 1,300 acres in extent, with a minimum depth of water at low springs of 18 feet. The quay is 750 feet long, with water to allow any vessel to discharge without grounding.

You are all aware of the improvements effected of late years, and going on at the present moment, in the River Liffey. Mr. Stoney's skilfully-devised plan of laying a quay wall in short lengths, but in blocks forming the wall for each length up to low water, and the perfection of the machinery necessary for carrying it out, have most deservedly commanded our universal admiration. Last evening the full description of these works was read before the Institution of Civil Engineers in Great George-street, and will ere long be in our library. I cannot help expressing my regret that our archives are not the repository of the history and details of such an Irish Engineering work, but of course there are cases, and this is one, where the author of an unique work is right to go to the very highest authorities for criticism, and, beyond doubt, praise.

The improvement in the manufacture of Portland cement, so largely employed in Mr. Stoney's blocks, of late years has been very marked, owing very largely to the supervision exercised by the engineer of the Main Drainage of London, Mr. Bazalgette, who not only used it extensively, but took the greatest precautions in testing it, so that the manufacturers began to learn how to make a better article.

Portland cement concrete has been used to some extent in building the carcases of houses, and it is said to be very economical, and form a better wall in every way than brick or stone masonry. This may be so, but the method should be adopted with caution, and under professional supervision; for

if, especially in the country, the system of building concrete houses with unskilled labour and untested cement be tried, the result may be disappointing.

I should not omit to mention that concrete blocks of large size, from 100 to 120 tons, were used by Mr. Barton at Greenore.

Among the sea-works deserves to be mentioned the new harbour of Rosslare, in the County of Wexford, now in course of construction by Mr. Purdon, under the immediate supervision of Mr. Martin J. Farrell, member of this Institution.

In this work Portland cement concrete is almost exclusively used. The design of this harbour is peculiar, from the nature of the locality. Owing to the sand banks and currents along this coast any solid projection from the land into the sea would at once collect round it a bank of sand, and become perfectly useless as a pier or breakwater. Mr. Purdon designed the structure now in progress of erection, consisting of a viaduct, as it were, of girders on piers of concrete stretching out for a considerable distance from the land, and terminating in a pier in deep water. The object of this form of construction is evidently to leave the shore currents unobstructed, and the normal depth of water will then remain.

This plan of providing against silting is of ancient date. The harbour of Antium had piers of this description over 1,800 metres, three English miles, in extent, and the present port has about 200 metres of perforated pier.

Bouniceau,* in describing this design, alludes to it as "a plan of the ancients, which for them was a step in advance, but for us would be retrogressive;" but he adds immediately, "what I have said must not be taken in an absolute sense, and it is not impossible that if one had to construct a new harbour, and more particularly a new roadstead, one could provide by means of a well-arranged pier in deep water with passages to

* "Etudes et notions sur la construction a la mer." Paris, 1866.

the harbour for keeping up a moderate agitation and certain currents, which would, without an annual cost, maintain the original depth of water. This truth," he says, "must never be lost sight of, and I constantly repeat it, that there is no absolute and general rule in sea works." I have no doubt that the harbour of Rosslare will justify these last remarks, and become a type for similarly circumstanced future works.

Since 1860 several important lighthouses have been erected, besides numerous small works, beacons, dwellings, &c., carried out by the Commissioners of Irish Lights. Light-houses.

The Calf Rock Lighthouse, erected by Mr. Henry Grissell, of London, at a cost of £25,000, is a cast-iron structure, lined with masonry, similar to the Fastnet Lighthouse. It is 60 feet high, its base being on the top of the Calf Rock, off Dursey Island, on the west coast of the County of Cork. It is in a most exposed situation, and it was with the greatest difficulty the work was carried out.

At one time several weeks elapsed without a landing on the rock being possible, during which time the men on the rock—some fifteen in number—were huddled together in a small cabin on the top of the rock, over which the sea constantly broke.

New lighthouses have been built at Arranmore, Blackrock, and Blacksod, and at Innistearaght, off the Blaskets, County Kerry.

Large repairs, costing over £14,000, were effected to the Fastnet Lighthouse under the following circumstances. In 1865, when I was acting as Consulting Engineer to the Commissioners, the reports of the action of the sea on a chasm in the Fastnet, nearly under the tower, were such as to induce the Board to solicit in addition the advice of the Engineer of the Scotch, or Northern Lights, Mr. Thomas Stevenson, and the Engineer to the Trinity House, Mr. James Douglas, who both were kind enough to at once

respond and visit the rock. The result of our reports, and a consultation in London, was that it was decided to build up the chasm with granite, carefully dowelled, and let into the rock on each side, and to add to the stability of the tower by an additional casing, not only adding considerably to the width of base, but also to the weight. These works were afterwards ably carried out by Mr. Sloane, the present Engineer to the Commissioners. It was for this extra casing that barytic concrete was first proposed by me, but not thought desirable at the time by Mr. Douglas.

One most requisite lighthouse remains to be built, namely, on Coningbeg Rock, a most difficult position certainly, but I have no doubt Mr. Sloane, the Engineer of the Irish Lights, will not fail to cope with it if directed.

An attempt was formerly made to put a pile lighthouse on this rock, but it was carried away, in my opinion, by a vessel being wrecked on it.

A great improvement has of late been introduced by Mr. Wigham, of this city, whose invention of lighting the lighthouses with gas has been extensively adopted, and will probably replace the old lights entirely.

Tramways In the year 1857 Mr. Le Fanu sent me over to Birkenhead to examine and report on the tramway then just completed by Mr. F. Train.

This was, I believe, the first instance in England of a regular street tramway. The rail on the straight portions was of rolled iron, and on the curves, round the corners of the streets, of cast iron. The rails were laid like the present tramway rails, but were quite different in section, as they presented an elevation of about an inch over the surface of the road *on* which the wheels *rolled*, instead of presenting no projection, but having a narrow groove to receive the flanges of the wheels. A short length on the same system was laid in Westminster, but ere long ordered by the authorities

who had given permission for it to be removed as a nuisance.

For many years nothing more was done in this direction, until in 1870 application was made to Parliament for powers to lay a tramway on the south side of the Thames. The great convenience afforded by the roomy cars and the smoothness of the running caused them to be greatly used, and the system rapidly extended to other parts of London, and almost all the great towns, at length reaching ourselves here. In 1867 the Corporation of Dublin, who had the power to do so, granted leave to a company to lay down a tramway from the Exhibition to Kingsbridge, on the same route as that now used. The funds for its formation could not, however, be found, and a project, which we now know must have been a most paying one, was slowly dying out, when it was purchased by the Dublin Tramways Company, which was started through the energy of Messrs. Fisher and Parrish, who had constructed the London Tramways, and of Mr. Barrington, of this city. The total length of lines authorized by this Company's first Act was seventeen miles, which has been extended by a subsequent Act, authorizing an extension from Donnybrook to Blackrock, and some small connexions. Of the authorized lines, that from Nelson's Pillar, by North Circular Road, to the Phœnix Park, the branch to Glasnevin, and the extension to Blackrock, have not yet been commenced. The opened tramways may be divided into five routes:—

Exhibition to Kingsbridge.
Nelson's Pillar to Rathmines.
Nelson's Pillar to Donnybrook.
Nelson's Pillar to Sandymount.
Abbey-street to Dollymount.

Some of these routes must clearly be far more remunerative than others. It would be most useful and interesting to know

what amount of traffic is sufficient to pay for the working expenses. In future projects it would be a useful guide, as clearly to construct unremunerative branches is to weight the capital unfairly.

Streets. Of recent years many improvements have been introduced into the formation of streets. I would especially call your attention to the new improved wood paving in London. Mr. Haywood, the Engineer to the Commissioners of Sewers of the City of London, in reporting on the differently-formed streets in his charge, speaks very highly of this paving, which is thus laid:—the street having been excavated and levelled, a close sheeting of creosoted deal, one inch thick, is laid down, and on top of this another similar sheeting is laid crosswise; the blocks of which the roadway is formed, and which are made by cutting ordinary deals into lengths of five inches each, are then laid in rows three-quarters of an inch apart and breaking joint, the grain of the timber being vertical; into the spaces between the rows is then poured a concrete of gravel and tar, which is tightly rammed. The surface is then sprinkled with fine gravel, and, the timber being very soft allowing the particles of gravel to get bedded into it, a very smooth roadway is produced, without its being slippery.

This paving has been laid for some years in King William-street, London, where it has been severely tested, especially round the statue, the street being inclined, not only longitudinally but transversely, and recently it has been tried on the steep gradient of Ludgate-hill with perfect success. Mr. Haywood, in reporting on the relative merits of granite, asphalt, and wood paving, gives some very interesting statistics. A horse, it appears, may be expected to travel without an accident for 132 miles on granite paving, for 191 miles on asphalt, and for 446 on the improved wood paving. Mr. Haywood tells us that,

whatever was the nature of the accident, the horses recovered their feet more easily on the wood than they did on either granite or asphalt. The weather had a marked effect. Thus, when the asphalt was merely damp a horse would, on an average, fall once in 125 miles, when it was wet the horse would go 192 miles, and if dry the distance would be 223 miles. Dry granite was very slippery, a fall occurring, on an average, once in 78 miles. When the granite was damp the distance became 168 miles, and when wet 537 miles. On wood, when damp, the accidents were one in 193 miles, when wet one in 433, and when dry one in 646 miles. Of those accidents which are most destructive to horses, asphalt had the greater proportion, granite the next, and wood the least. This method of forming streets appears, then, to have succeeded in the greatest thoroughfares of the world, and is deserving of being better known and more extensively used.

Sanitary Engineering.

Sanitary engineering is daily acquiring more and more importance; the necessity for a thorough system of sewerage and a full supply of good water is being recognized. Here, in Dublin, we have a most perfect water supply; and I was glad to see it stated lately by the Chairman of the Drainage Committee of the Dublin Corporation, that there was every reason to hope that the new sewerage works would be commenced within the current year. Cork, Belfast, Sligo, Newry, and other towns, have found the advantage of spending considerable sums in securing a supply of water, and Wexford, Wicklow, Tralee, and many others, are about to follow their example. Under the Local Government Act facilities are afforded for originating or improving the sanitary conditions of towns, which, no doubt, will in time be almost universally availed of. The cost of such works as the Vartry Reservoir, one of the largest and most complete engineering works of late years in Ireland, with its many

miles of conduits, and the subsidiary reservoirs, may, perhaps, frighten town authorities to some extent; but, on the other hand, it should be known that many small towns have had a water supply provided at a comparatively trifling expense—some at their own cost, others at the cost of the proprietors, as Cappoquin, Lismore, Enniscorthy, Tallow, &c. They may not have a constant supply, nor any very great pressure, but the advantage of the boon is not the less felt.

True time. Several years ago the Port and Docks Board conceived the idea of obtaining the correct time for their time-ball by means of telegraphic communication with Dunsink Observatory.

Various causes prevented this plan from being carried out until quite recently—in fact, it was only this very day that the connexions at the Observatory end of the wire were permanently established.

The telegraph wire is supported on posts along the road from Dunsink to Dublin up to the point where it crosses the Midland Great Western Railway; it then follows the line of telegraph posts along the railway, and reaches the Post-office, from which a wire is laid to the office of the Port and Docks Board in Westmoreland-street.

The wire is there led through a galvanometer placed beneath the clock, which, by an electro-magnetic arrangement, drops the time-ball at one, p.m., daily.

A signal is sent which deflects the needle of the galvanometer, say to the left, exactly at twelve noon; and at one minute after twelve the needle is released—thus the mean of the two signals will be subject to a less error than either of them separately.

The electric battery is on the Post-office, the line wire is put to earth at Dunsink, and the signal is sent by making or breaking contact at the Observatory.

This arrangement is capable of giving the time with very

considerable accuracy. It is, however, only temporary; for it is proposed to adopt the system known as Jones' electro-sympathetic clocks.

The principle briefly is this:—A clock in the Observatory, which is regulated by comparison with the sidereal clock—one so kept to correct time—*controls*, by means of an electric current, other clocks placed in electrical connexion with it.

The bobs of the pendulums of these clocks are hollow coils of wire through which the current circulates. The pendulum in its vibration oscillates over the opposite poles of a pair of permanent magnets, the effect of which is on Ampère's principles of the mutual action of currents and magnets, to make the controlled pendulum to oscillate synchronously with the controlling, retarding if the tendency is to gain, and accelerating if the tendency is to lose.

I am aware that arrangements have been made to provide the requisite clocks, and that the difficult task of constructing them has been entrusted to our eminent fellow-citizen, Mr. Booth, of Stephen's-green, and with the assistance of Mr. Yeates in the electrical arrangements necessary, there can be no doubt that the plan will succeed.

We may congratulate ourselves on the facts that the time will be given by our *Irish* Observatory, the arrangements made by an *Irish* electrician, and the clockwork carried out by an *Irish* horologist.

And now a few words as to our position as a Society.

The Institution.

Mr. Mallet, in his Address to you in 1866, sketched out the history of this Institution to that date. He dilated on the advantages that the Institution had gained by the refuge afforded it in this seat of learning, when it was in danger of collapsing from financial embarrassment. We all endorsed Mr. Mallet's views at the time, but the subsequent course of events has shown that if at a former period the Institution was in danger of collapsing from one cause, we were drifting

into a hopeless state of inaction from another—namely, the want of interest taken in our proceedings by our members. Month after month was passing away without any paper being brought forward, and my duty in this chair was becoming absolutely nominal. This state of things was considered by some, to whose opinions the greatest deference is due, to be owing to the delay and irregularity of our publications.

I and some other members took the view that the best chance of restoring life to our body, and of making it what it ought to be, was to move our head quarters out of Trinity College, into a convenient part of the town, where, on a smaller scale, we might afford to our members similar advantages to those given by the Institution in Great George-street, Westminster.

Owing to the munificent bequest of the late Mr. B. Mullins, an opportunity was afforded of doing this, with hopes of financial success; and I may mention that this use of the income bequeathed to us met with the most cordial approval of the executors, whose consent was necessary to the employment of the fund.

Mr. Mullins, as you are aware, beside the munificent gift of £1,200, left to us all his engineering and architectural books, and we have now the nucleus of a useful library.

The rooms of the Institution in Stephen's-green will very shortly be open daily for the use of Members and Associates, and I hope the convenience and advantages offered, especially to those who reside in the country, will be such as to draw to our ranks all the members of our profession who should be members of our body, and also gentlemen of other callings and professions, "whose pursuits," to quote the qualification of an Associate, "constitute branches of engineering, or qualify them to concur with Civil Engineers in the advancement of professional knowledge."

It must not for a moment be supposed that the relation between an Associate of our body and a Member is necessarily one of *degree*. Except in the case of very junior Engineers, it is one of *kind*. In the list of Associates of the English Institution I find the well-known names of Tyler, Chesney, M'Kerlie, with 53 other officers of the Royal Engineers; Abel and Herapath among the chemists; Brassey and Peto among the contractors; Sir J. Brown, Bessemer, Krüpp, Vickers, Maudslay, Aveling, among the mechanical engineers; Lloyd and the Solicitor-General among the barristers; and Cawkwell, Myles Fenton, and James Forbes among the railway managers. No names in England, or the world, stand higher than these *Associates* of the Institution in Westminster, and I trust to see our list of Associates expanding to include nearly, if not quite, as well-known names in Ireland. Most especially would I like to see enrolled with us the managers of our Irish railways. Railways form the subject of papers very often, and in a discussion on such subjects the greatest assistance may be derived from gentlemen who make one department of them their daily study.

Anxious as I am that the new arrangement should be a success, I would not for a moment advise a lowering of professional standard for the purpose of financial gain. I would, however, ask our members to join me in looking around for those who, perfectly qualified as Members or Associates, are perhaps ignorant of the advantages they will receive by joining us. Such canvassing, if canvassing it can be called, is, in my opinion, not only perfectly legitimate, but more—a duty. Not only will our position be secured, but our standard be raised and more recognized outside.

[March 18th, 1874.]

C. P. COTTON, President,
In the Chair.

The following Candidates were ballotted for and duly elected:—

FREDERICK ARNOLD CARROLL, WILLIAM CARROLL, JOHN CROSTHWAIT, JOHN LIONEL LYSTER, and RICHARD WILSON, as Members; THOMAS ARTHUR BEWLEY, JOHN EDWARDS, THOMAS EDWARDS, WILLIAM J. DOHERTY, GEORGE MURRAY ROSS, and GEORGE ALEXANDER STEPHENS, as Associates.

On the PREVENTION *of* RAILWAY ACCIDENTS. By JOHN CHALONER SMITH, Member.

WHEN the benefit is considered which the great Railway system now existing has conferred upon the human race, and the rapidity with which it was executed, it may not be strange that those who have been instrumental in carrying it out should feel a degree of pride at the result of their labours; but this pride must be tempered with considerable mortification by the reflection that there has been, to some extent, failure in a particular which essentially distinguishes the civilized and intellectual man from the savage—namely, the successful regard paid to the preservation of human life.

It may be alleged, and, no doubt, with truth, that Railways are much safer than any of those modes of transit which they have replaced, as is proved by the smaller proportional number of casualties; and that the loss of life by Railways is less than that caused by street accidents, by mining catastrophes, or by shipwrecks; and, furthermore, that in these countries it is less than in America, or on the Continent. Still, these arguments are mere excuses; and if comparison

is to be made, let it be made with what is worthy of imitation; let it be made with the marvellous accuracy and unerring precision with which the Creator guides and controls the great powers of the universe—force, to which the united steam engines of this globe could offer no obstacle; weight, of which the heaviest goods train is the merest infinitesimal portion; velocity, compared to which the fastest express is almost at a stand-still.

In the proceedings for 1847 will be found a paper bearing the same title as the one which has now the honour of being laid before the Institution, read by the then President, the late Colonel Harry D. Jones, in which he suggested a plan of avoiding accidents by having a look-out man placed in a watch-box attached to the leading carriage of every train, and who should have the power, by means of a mechanical arrangement, of instantaneously separating the train of carriages from the engine, whenever he considered that there was occasion to do so.

No such panacea will be brought forward now. As the causes of disaster are various, so, also, must be their remedies.

These causes, and the statistics connected with them, are taken from the last Report on Railway Accidents to the Board of Trade, ably drawn up by their Inspector, Captain Tyler, being that treating of the accidents which occurred during the year 1872 in Great Britain and Ireland.

In the latter country the railways appear to have been worked with greater security on the whole, the gross traffic being as 1 to 18, the fatal accidents there have been as 1 to 26 of the entire, but the same causes of accident are evidently present, so that the tenor of the following observations would not be affected by this fact, neither would the including of the statistics of former years materially alter the aspect of the case.

The press and general public take notice, mostly, of one

particular class of accident—namely, that arising to passengers from causes entirely without their own control. It may, therefore, surprise some to hear that, in 1872, these were little more than one-fiftieth part of the total deaths, which amounted to 1,145, and will be considered in the order of the number of the different classes.

It is not necessary for the purpose of this paper to take into consideration the numbers of injured given in the report—indeed they would, perhaps, only tend to mislead, as no distinction is made between the most serious and the most trifling hurts; but about the deaths there can be no mistake.

Railway servants killed.

As might be expected, the Railway servants are the most numerous, and the deaths resulting from what may be considered the negligence, or want of caution, of the sufferers themselves were 592, viz.:—

Killed when shunting, - - - -	130
Killed when joining or leaving vehicles, - -	116
Killed from coming in contact with bridges, &c., -	5
Killed when loading goods, spragging wheels, or working cranes, - - - -	10
Killed when working on permanent way, or in going to or returning from work, - -	160
Killed in crossing, or when standing on line, -	118
Killed when passing between vehicles, - -	27
Killed while attending to gates, machinery, &c., -	26

No data are given to enable an opinion to be formed as to what number of these were caused by placing comparatively untrained hands in positions dangerous to those not having experience, but as the oldest servants are often caught, it is possible that this may not have been a main cause.

It appears at any rate, however, that the chances of each Railway servant being killed in six years of his service, are as great as if he stood in the British ranks at the battle of Waterloo; and Captain Tyler is of opinion, moreover, that if

the whole truth could be ascertained, he would have to report a considerably increased number of deaths of Railway servants.

Besides all these, 42 servants were killed by accidents to trains resulting from the negligence of fellow-servants, or from the accommodation to meet the requirements of the traffic being insufficient or defective; and these caused also the deaths and injuries to passengers for which Railway Companies have to pay such heavy compensation. Negligence and compensation.

It may be remarked (particularly since the recommendation of the Royal Commission on Railways, in 1867—that there should be a maximum amount of compensation for each class, and that passengers might insure beyond this—was not adopted), that it seems utterly impossible for the Companies to alter the law or mode of procedure in these cases. Public opinion firmly believes that, were it not for these enormous compensations, accidents would be much more frequent, and it is vain for the Companies to attempt to argue the point; yet it does seem unfair that the punishment, instead of falling upon the person or persons whose negligence has caused the injury, falls upon the unfortunate shareholder, who, generally, has nothing whatever to say to it, and who has spent his money—with a view to his own benefit, it is true—but, certainly, to the great advantage of the public.

This negligence, too, is often a very complicated question, and it seems a very clumsy way of coming at the truth to leave it to a jury, who are quite ignorant of the details of the subject. And there is a still worse evil, for it is often the direct interest of the Company to screen the person or persons in fault, as, if they punish them, the so doing will be relied on as evidence against the Company.

The negligence which has occasioned this loss of life varies in degree from gross misconduct to simple forgetfulness, or slight error of judgment, and can never, as far as it is

possible to foresee, be entirely got rid of. Captain Tyler says, "The item of human fallibility will still remain," but it will clearly be much diminished if additional means be adopted tending to enforce discipline and obedience to orders, to increase steadiness and careful habits amongst the men, to discourage their working in a hasty and bustling manner, without their wits about them, and to the effectual punishment of disobedience to orders.

Pensions.

Now, in other continuing services, such as the army, navy, and constabulary, the granting of good-service pensions has been found useful in producing such results. Might it not be worth while to adopt it in Railway service?

It is not asserted that directors or shareholders generally neglect their old servants; but there is—or the men think there is—an uncertainty in the matter, and to produce the good effect desired, the men should know that if they, for a certain number of years, yield good service to the Company, that they will be entitled, as a matter of right, to a pension, according to their position and length of service.

The publication of such an arrangement would also have the effect of making many competent men anxious to join, and would, therefore, tend to prevent the rate of wages having to be raised in a manner disproportionate to that in other pensioned services.

Trespassers.

The number of trespassers killed on railways in 1872 was no less than 224. Captain Tyler observes that this number "might perhaps be reduced by more stringent provisions." Now these provisions are as follows:—

Act of 1840.—"If any person shall wilfully trespass upon any Railway, and shall refuse to quit the same on request being made by an agent of the Company, he shall be liable to a penalty not exceeding £5."

Act of 1868.—"If any person shall be on any Railway, except for the purpose of passing the same at an authorized

crossing, after having received warning by the Company, he shall forfeit and pay any sum not exceeding 40 shillings."

Act of 1871—Introduces the word "once," making the foregoing read "after having once received warning."

It may safely be assumed that every reasoning being in the kingdom knows that it is wrong and dangerous to trespass on the Railways. Yet they continue to do so, for the sake of a dry walk, or a short cut, and sometimes—and these are generally people who should know better—from mere bravado and defiance of the Company's regulations.

A trader, having unwittingly incorrect weights, even though they should be in favour of the customer, is punished without warning; drunkenness and other offences committed without wilful bad intent, are punishable without warning; it is, therefore, difficult to see why the Legislature require it in the present case. It has, probably, cost hundreds of lives, and the warning to many has been a locomotive tearing them to pieces.

Should the warning be omitted by the Legislature, Railway servants will have no difficulty in preventing trespass, and they can be punished if they connive at it. At present it is almost impossible to get them to understand the law (particularly as notice boards are not legally held to be warning); and, if they carry it out, it takes much time from their proper work. The magistrates also would be able to use their judgment with regard to the amount of penalty to be inflicted.

The number of those—not servants or passengers—killed at level crossings was 70. It is not stated how many at public and how many at private level crossings.

Public level crossings are sometimes practicably unavoidable; but they are very objectionable both to the Railways and to the public, and many might be got rid of by a little concession on the part of the road authorities. Public crossings.

Private crossings.

In the Act regulating the shutting of gates of private crossings the direction is that each gate should be opened and shut successively. This, if carried out, might involve the cattle having to stand on the line, while the attendant was opening the second gate; but, generally, the attendant opens both gates, drives the cattle across, and then shuts both gates. An alteration, therefore, of the Act would probably be desirable; and there might also be power given to the companies to remove gates, when the lands on each side of the line became vested in different hands.

Next, and saddest of all, are 33 wretched suicides.

There were also 57 people—not servants or passengers—killed from miscellaneous causes, to be imputed to their own want of care in various ways.

The deaths remaining to be considered are those of 127 passengers.

Of these 48 were killed from falling between carriages and platforms, and 10 while getting into or out of trains. To these the passengers' own hurry and neglect, no doubt, contributed; but Captain Tyler well remarks on the importance of uniformity of construction between carriages and platforms, and of filling up the space between them by means of continuous foot-boards.

Crossing the rails.

Next are 39 killed while crossing the lines of rail at stations; this, the system adopted by the Metropolitan Railway, would entirely obviate. It is—having the booking offices so placed (such as on the top of the covered way in which the line runs) as to give direct access to each platform from them, and also to give direct exit from each platform without there being any necessity for the passengers to go down upon the rails.

As it is, most Railways have their intermediate stations with the office on one platform, the public approach behind the office; and in the case of a double line, or of a passing station

on single line, there is no way for passengers to get to the opposite platform without crossing the rails.

To remedy this, foot-bridges are sometimes put up, but they have not been generally adopted, nor are they amongst the requirements of the Board of Trade; the great objection to them is that passengers will not, as a general rule, use them, but will continue to cross the rails, as being shorter and less troublesome than going up and down the steps of the foot-bridge.

As a road over or under the Railway frequently adjoins a station, it might be advisable, in such cases, to consider whether, instead of constructing a foot-bridge, it might not be better to place a small booking office on the road approach, as shown in Fig. 1, Plate XI., and to have the platforms connected separately with the road by steps, or, what would be still better, by inclines.

Six passengers were killed by falling out of trains in motion, two from falling down stairs at stations, and three from other accidents; leaving nineteen killed by accidents to trains; and the return for last year will, unfortunately, show the number under this head nearly quadrupled.

Captain Tyler gives a most elaborate and careful analysis of these train accidents, which numbered 238 in the year, and from the experience acquired by investigating into their causes, and also into those of previous years, he advises nine principal means of safety shortly as follows:—

1. Maintenance in high condition of the permanent way.
2. Good axles.
3. Tire fastenings, to prevent the tires flying in case of fracture.
4. Improved couplings.

On these, it is to be remarked, that not only are they a principal means of safety, but that, especially in the case of the first, with which the author is most familiar, they are the most truly economical for the Companies themselves.

Signals. The fifth means refers to signal and point arrangements.

In the comparatively early days of Railways the exhibition of a danger signal, which was generally a vane or disc, on a post at the platform of a station, was a warning to the driver of an approaching train to stop, and by degrees it came to be the rule that drivers might come up to a danger signal, but were not to pass it.

Many stations were so placed on curves that the driver of an approaching train could not see the signal in time to stop his train before passing it, and, therefore, what was called an auxiliary was put up in a position having a sufficient range of view for drivers to stop; this was worked by a wire from near the main signal, and the directions were that it should show the same as the main signal—Danger, Caution, or All right, as the case might be.

The use of these auxiliaries having been largely increased, it was found that stopping a train outside them exposed it to the risk of being run into by a following train, and, therefore, this rule was made, the name being changed from auxiliary to distant signals.

"DISTANT SIGNALS.—Enginemen are to stop their engines in obedience to a distant signal. Having done so, they are, without a moment's delay, to bring their train forward as far as the line may be clear, at a speed not exceeding five miles an hour, until the whole train be well within the distant signal, so that it may be protected by the distant signal from any engine or train following. Should it not be practicable to draw the train far enough to be protected by the signal, the guard must at once hasten back a sufficient distance, with the necessary signals to protect his train. The guard must perform this duty whether a train be due or not. It must be borne in mind that the same signal is always exhibited by the distant and station signal."

The inconvenience and delay to trains caused by guards

having to go back with hand signals to protect their train when it stopped, were very great, and as this rule prevented a good deal of it, distant signals were considered a great improvement, and were also strongly recommended by the Inspectors of the Board of Trade, who will not allow a new line to be opened unless each station is provided with distant signals in both directions, as well as with a main signal having two arms, one for each direction, and which is called by them the home signal.

No distinction is required to be made between danger signals as given at the home signal post and at the distant signal post, yet the driver is not allowed, under any circumstances, to pass the first, and he is habitually allowed, under the conditions of the rule, to pass the second; and it is well known to railway officials that drivers, almost universally, understand these conditions to mean that they are to pass the distant signal, when at danger, with caution; and therefore they do not stop, but they slacken speed, so as to be able to stop before meeting with what they expect to be the obstruction, and yet the station agent generally relies wholly upon the distant signal, when he has the line between home and distant signals blocked.

As might naturally have been expected, a plentiful crop of accidents has arisen from this state of things, of which several are mentioned in the Report of 1872.

The author recollects maintaining, many years ago, that auxiliary signals should exhibit caution when the platform signal was at danger, but the argument used against this was, that drivers never attended to caution signals, which was to some extent the case; but the rules for distant signals result in a much worse thing, for the drivers do not attend to danger signals.

It may be assumed as an axiom, that unnecessary signals should be avoided, but that signals, when exhibited, should be

strictly obeyed, and on this basis the following are submitted as principles for the re-arrangement of signals:—

Proposed rules for signals.

That stations be protected by two main signals, one on the up side for down trains, the other on the down side for up trains, with an interval between sufficiently long to secure trains standing at platforms, or shunting, when there are cross-over points or sidings.

Should this interval be considered in certain cases too long, a second signal may be used beyond the main signal, to exhibit danger whenever there is an obstruction between it and the main signal.

When the range of the main signal is not sufficiently long to give the driver of an approaching train ample space to stop if the signal be at danger, one or more auxiliary signals are to be used, and they are to be arranged to show caution when the main signal is at danger, as a warning to the driver that this is the case; means should also be provided whereby, in the event of an obstruction between the auxiliary and main signal, the servants of the company can put the former to danger.

In the case of junctions there should be main signals for each line, placed clear of all possible fouling; in the case of level crossings the single post with two arms would be sufficient; auxiliaries to be added if requisite in either case.

The working of the signals in all these cases to be concentrated.

The main signal posts at stations may be utilized for starting signals for the trains.

There is, no doubt, great objection to changing a system which has been so extensively adopted as that of distant signals, but there exists a means of doing it in, humanly speaking, perfect safety; and the author finds words too weak to express his sense of the importance of drivers becoming *habituated* to regard danger signals as *never* to be

passed; these distant signals tend to cause a mental confusion in the driver, which may be followed by the worst consequences, even though it be only momentary.

Signals not only perform the duty of warning drivers of obstructions, but they also show them that the points are made for the line on which it is intended that they should run, and consequently these points should be so made before the signal be given for the train to advance. Interlocking system.

In 1858, the author made a rude attempt at a junction, of which he was engineer, to obtain a combination of action between points and signals, not being aware that at the time abler hands had taken up the idea, and their efforts have now resulted in what is familiarly known as the interlocking system.

In April, 1868, a paper was read before the Institution by Mr. Bailey, now Vice-President, describing Anderson's apparatus for this purpose, and since then the principle has been further developed, especially as regards the distance at which points can be worked from the signal-box, which has been done by means of compensating bars, up to over 500 yards.

Plate XI., Fig. 2, shows the working as applied to a terminus, where the exigencies of the traffic require that some of the up trains should run to the down platform and some of the down trains start from the up platform.

All points being open, signals A and D may be lowered.

Points 7 and 1 being made, signal C may be lowered.

Points 3 and 2 being made, signal B may be lowered.

Points 5 and 6 being made, signal D may be lowered.

Points 4 and 8 being made, signal A may be lowered.

In these cases points not mentioned as being made are locked in open position, and signals not mentioned are locked to danger.

There is also a position of the apparatus whereby, when all

the signals are locked to danger, any of the points may be opened for shunting purposes.

The cost of this improvement varies with the circumstances of the case. In this instance it effected a saving in the number of points and signalmen which, in three years, equalled the entire outlay for erection, leaving a substantial annual gain to the company. This, of course, may not always be the case; but the main question is whether it be an alteration for the better or not, for the author believes that the Railway men, whether directors, shareholders, officers or servants, who would grudge money, time, or trouble, in endeavouring to avoid accidents, would be found an insignificant and contemptible minority.

Facing points.

Captain Tyler also recommends locking bars, whereby facing points may be held in position whilst trains are passing, and considers that the use of this class of points should be as restricted as possible.

Fouling of sidings

His next means of safety are switch tongues behind the fouling point in sidings connected to main lines.

The danger which this is intended to meet used to be provided against by stop blocks, but the switch tongues are far more effectual, and they can be arranged as those numbered 5 and 4, shown on the figure are; or, if there be no blind siding, a single tongue, worked in connection with the main line points, to be open when they are open, or *vice versa,* will answer.

Next is increased use of the telegraph to secure intervals of space between trains.

Collisions.

More than three-fourths of the train accidents mentioned in the report are collisions, which may be considered under the following slightly abbreviated classification:—

I. Collisions with fixed obstructions at stations.

II. Collisions with obstacles at junctions, stations, and sidings.

III. Collisions between trains running in opposite directions on a single line.

IV. Collisions, in consequence of one train overtaking another moving in the same direction on the same line.

As regards No. I., everything depends on the driver; and it speaks volumes for the skill and caution of these men that only seven accidents of this class are reported.

Arrangements of points and signals to prevent No. II. have been mentioned, above all to make drivers respect danger signals as they do buffers.

The staff system is intended to obviate No. III., and the block system No. IV.

Staff and block systems.

The staff system is that no engine should run upon a certain portion of line without carrying a staff, used for that portion, and no other.

The block system also divides the line into parts, say, A to B, B to C, and so on; and when a train is started from A, A telegraphs to B, LINE BLOCKED, or TRAIN IN, and until A has received an answer from B, A will permit no other train to follow.

Both these systems are theoretically perfect—that is to say, their provisions being carried out, no collision can ensue; mistakes as to carrying them out will, most likely, from time to time be made, but it does seem placed beyond the region of doubt, that lines worked under these systems are infinitely safer than those worked without them.

The staff is only adapted for single lines, which in Ireland constitute three-fourths of the Railways, and are now all, as the author believes, worked under that system.

It frequently happens that on single lines it is necessary to despatch two or more trains in one direction, say from A to B, before a train runs in the opposite direction, from B to A. In such a case the first train from A to B would be started with a ticket, provided the staff was at A at the time. This

ticket would not enable that train to reverse on the journey, but would authorise its running through.

Now this makes the Staff system theoretically imperfect, because there is no provision made by it to prevent this train carrying a ticket from being run into by a following train.

To obviate this imperfection, with a minimum amount of telegraphing, perhaps it might answer to print on the back of the tickets—

"Station A to Station B.

LINE BLOCKED.

No (up or down, as the case may be) train will be despatched from A until B has telegraphed to A that the train carrying this ticket has arrived at B."

This information could be conveyed by a signal not requiring a skilled telegraphist, and, consequently, the expense of adopting it would be trifling; the additional delay would be very little indeed, and the receipt of the ticket would prevent the agent at B from forgetting to telegraph, and the agent at A would know when to expect the message; and the use of these tickets might be commenced on the portions only where the greatest risk is now incurred.

This combination of staff and block will probably be found more effective than the block only, under which accidents have occurred on single lines, which could not have happened if they had been worked by the staff.

The adoption of the block system for double lines is strongly recommended by Captain Tyler, who shows that 42 collisions in 1872 might have been avoided by its use; and, certainly, it has not been less urgently required since. Mr. Harrison, also, in his inaugural address as President to the Institution of Civil Engineers, in London, on 13th January last, makes the following weighty remarks—"It might be considered as settled that the block system would, as soon as it was possible to complete the necessary works, be intro-

duced throughout the whole of the Railways in the United Kingdom; and that, although it had been demonstrated that enginemen did not keep the same look-out under the system as on lines apparently less protected, and that the large increase of the number of signalmen (in one case 300 per cent.) would increase that element of danger, 'human fallibility,' yet he did not mean to argue from these against the introduction of the system, though they might sometimes make Railway officials hesitate to recommend it."

The first of these objections has been mentioned by Captain Tyler in the 23rd page of his report, and the author may, perhaps, quote a maxim of an old friend and brother official of his own, whose long experience on Railways entitles his judgment to be considered sound, which is "that the more accommodation given to men for doing their work well, the better that work will be done."

With regard to the number of signalmen, that is clearly a function of the number of trains; the more frequent these are the shorter must be the interval between them, the principle of the block being the same, whether the interval be 100 yards or 100 miles. In Ireland the station signals might probably, for the most part, be utilized for the purpose, the working of them being concentrated to where the block telegraph instruments were placed.

It is highly desirable that there should be a method, so to speak, of interlocking the telegraphs and the signals which would prevent the possibility of the signalman making mistakes. M. Spagnoletti claims to do this by using treadles instead of signalmen; thus:—"On a train leaving A, it passes over a treadle which puts the signal to danger to protect it, and a bell is also rung at B, as a signal of its approach. On its arriving at B, it then puts a signal up, takes the signal down at A, and rings a bell at C, and so on throughout the journey."

It will be apparent that, under the staff and block systems, the re-arrangement of signals, and the abolition of the present distant signal, already alluded to, may be carried out.

In these systems great care must be taken to avoid contradictory signals; for instance, that a gang of platelayers should not have a rail out and a red flag exhibited, whilst semaphore signals at each side of them show "All right."

Sidings. The next means of safety is the providing sufficient siding accommodation. Of the best means of carrying out this, the officers of the various lines, who are acquainted with all the details, must be the best judges.

Breaks. The last means of safety mentioned in the report is the employment of continuous breaks, to be worked by engine drivers as well as by guards.

Break power is clearly necessary in proportion to the weight or velocity of the trains, and to the steepness of the gradients of the line; on the other hand it should not be so excessive as that its sudden application would be as bad as a collision: a vast number of different plans are proposed, on which the author has not sufficient practical knowledge of details to afford information. However, as several members of this Institution are thoroughly competent to deal with the question, he would suggest to one of them to write a paper on the subject.

No accident appears to have occurred in 1872, attributable to the want of intercommunication in trains—that much vexed question.

Concluding remarks. To conclude; it will not, perhaps, be denied, that the majority of the practical improvements, adopted from time to time in the working of railways, have been introduced by the executive heads of departments of the companies, and that it is chiefly from them that further improvements may be expected. These officers are responsible, not only that the alterations which they recommend shall be real improvements,

but also that there shall not be real improvements in existence which they do not recommend; and, therefore, it is of much consequence that they should have full opportunities of comparing their experiences, and that each should be able to submit his ideas to the test of examination by the skill and judgment of the others. One reason, perhaps, that improvements make their way comparatively so slowly is, that the time of these officers is almost entirely taken up with the details of their work, and they are also seldom able to leave the lines where their duties lie, in order to become acquainted with differences of arrangements on other lines. It is to be hoped that the discussion on this paper will prove that this Institution offers a means of overcoming, to some extent, these difficulties, and it is not likely that any one will have either the inclination or the power to resist the adoption of amendments or precautions which have met with the sanction and approval of the great body of Railway Officers.

[22nd April, 1874.]

CHARLES P. COTTON, President,
In the Chair.

The following Candidates were ballotted for and duly elected:—

MARTIN ATOCK, THOMAS F. PIGOT, JOHN SWAN SLOANE, as Members; EDWARD BARRINGTON, DECIMUS FITT, JOHN W. HOUGHTON, GEORGE EDWARD ILBERY, WILLIAM LABATT PAYNE, as Associates.

Discussion upon Paper on the "Prevention of Railway Accidents."

MR. C. G. NAPIER observed that the adoption of means to enforce discipline and obedience to orders gave the key-note

to improvement in railway management, in which much imperfection still remains in consequence of the rapidity with which the system had sprung up.

He fully agreed with the author's remarks on the Act regulating the shutting of gates of private crossings; also as to stations being protected by a set of signals at each end, there being no doubt that even now the signals at many stations are inadequate; but he considered that there should be also on each side a distant signal which should repeat the "Danger" and "All right" when exhibited at the main signal. When there is only one main or "Home" signal placed in the centre of the station and two distant signals, the protection of the station actually depends on the latter, for the point of danger may be reached and a collision take place without the train having come up to the main signal; but when there are two main signals, one at each end of the station, they really protect it, and the present rule for distant signals becomes good and safe, and their use may be clearly defined, viz., to repeat the main signal and extend its range, to warn the driver of an approaching train in case of a block at the station, and to protect his train while it is waiting outside the station, that is, while it is waiting *behind* the main signal.

He must confess that he was not fond of caution signals; a "Danger" signal is clear and definite, it means "Stop;" an "All-right" signal is also clear, it means "Come on;" but a "Caution" signal means anything you please; in obedience to it a driver may come on with full steam, ask him why, and he says—"Oh, I had a heavy goods train, the rails were greasy, and I had a very long incline against me; if I had shut off steam, I could not have brought my train to the station;" and he might be quite right. But suppose the incline, instead of being against him, had been with him, all other circumstances being the same, then he would be very

culpable if he did not shut off steam, and bring his train under complete control in obedience to a caution signal, for then stopping and not starting would be the difficulty. The fact is, no engine-driver would be worth his salt who did not always approach stations with caution, and it is more sensible, and therefore safer, to trust to the skill and experience of an intelligent human being than to an indefinite signal, the proper interpretation of which must, in the end, depend on the person who reads it.

The expansion and contraction of the wires by which it is worked also causes some uncertainty about the exhibition of caution with a semaphore distant signal; if it is a little too high it may be taken for danger, if a little too low for all right. The use of caution should, therefore, be dispensed with for distant, and very much limited for main signals.

As to breaks and break power, it seems astonishing that it should still be necessary for a Government Inspector to recommend the use of continuous breaks under the control of the driver. Suppose an ordinary case of stopping a train at full speed (say 45 miles per hour), with three breaks, one attached to the tender, one under the control of the front guard, and one in the hind van at the tail of the train, under the control of the hind guard; the driver sees sudden occasion to stop, he shuts off steam, whistles to the guards to apply their breaks, and applies his own, the front guard may or may not be looking out at the time, but he is close to the engine, and hears the whistle distinctly and directly, and perceives the alarm of the engine-driver, so he applies his break, but with a few seconds of delay; but the hind guard! he is some distance off, he does not hear the whistle so distinctly, nor at once recognize its alarm; he may be reading a newspaper, or the Company's rules about accidents, or his Bible, or what not—he may be mending his clothes, or cutting tobacco, for

remember he spends many hours in the van, and must be doing something—well, he hears a whistle, puts his occupation aside and his head out of the window to see "What can the matter be," cannot make it out, thinks he had better put on the break immediately, as directed by the rules, and he does so, but all this has, perhaps, taken 20 seconds of time, which would bring the train one-quarter of a mile nearer the point of danger, with one-third of the break power not applied, whereas if this had been under the control of the driver, he, from the very first moment of danger, would have brought the whole of it to bear, and from the nature of his occupation he must keep a constant look out, and first see the danger, must know better than the guards can possibly do the circumstances of the train, whether it be heavy or light, whether the rails be slippery or dry, what sort of incline he is on, and last, but not least, he knows that if a collision occurs, he *bears the brunt;* he has also the assistance of his mate in looking out, and altogether it seems beyond a shadow of question that the whole break power of a train ought to be placed under the control of the engine-driver.

Facing points have, perhaps, received more sweeping condemnation than they deserve; at junctions and stations on single lines where they are unavoidable the risk incurred is from the speed at which trains habitually run through them, rather than from their fair use; and the advantage they would frequently give at larger stations in shortening the time occupied in shunting is sometimes overlooked, for shunting operations are a fruitful source of danger; undoubtedly the practice so general of running through facing points at high speed is very objectionable.

Mr. J. DILLON remarked that the total number of persons killed and injured on the railways of the United Kingdom in 1872 was 4,183, a comparatively small proportion being from

causes beyond their own control, and these cases are fewer in proportion to the traffic in this country, thereby proving that the management is superior, as the mechanical parts are certainly not so perfect, as a general rule, here as in England and Scotland.

The practice of keeping railway servants at their posts for periods longer than they can give continuously proper attention to their duties is very dangerous, and in such cases the number of servants should be increased, and the working hours diminished.

He considered the principal cause of the accidents which have lately led to such a panic, was the practice of running passenger and goods trains in irregular order, and at different rates of speed, in quick succession at short intervals of time and space; signal and engine men were thus frequently suddenly called upon to deal with extraordinary combinations, not provided for by their rules, and with the best intentions, did the wrong thing; for example, a driver increases his speed to make up for lost time and keep out of the way of a following train, and runs into a preceding train delayed by some exceptional traffic or other accident.

The block system might answer for a line with moderately large traffic, but where the traffic is excessive the available time and space between the numerous trains must be so short that the signal stations must be at correspondingly short intervals, and thus seriously interfere with the progress of the trains, and diminish the carrying power, which is already too small on certain great trunk lines.

The only practical way to meet the difficulty would be to divide the traffic into "quick" and "slow," and have separate up and down lines for each, regulated by a uniform code of signals.

Accidents will occur from sudden breakages, through concealed defects which no human foresight can avoid, but the

rolling stock and permanent way should be kept in the most perfect working order, and to do this it is necessary for the Directors to authorize the engineers to expend a sufficient sum annually in renewals.

It is well known, however, that there are many Railway Companies in Ireland whose financial condition is such that it will not be in their power to keep the permanent way in safe working order much longer, and unless something be done to meet this difficulty by Government loans or otherwise, an increase of accidents may be expected to occur, for a considerable portion of the rails, sleepers, and bridges even now require renewal.

Mr. M'Donnell observed that it was often extremely difficult to detect flaws in axles. The more general use of steel axles and solid rolled steel tires was of the greatest importance. The average distance run by iron axles varied from 40,000 to 80,000 miles, according to the kind of engine in which it was used. He had in use 109 cast-steel crank axles, of which 54 had run from 80,000 to 217,515 miles, and only one of them had failed after running 112,316 miles. He did not approve of auxiliary signals exhibiting both danger and caution signals, as they could not be shown with sufficient certainty to insure the signal not being mistaken by the drivers on account of the contraction and expansion of the wires. He did not agree with the author of this paper as to engine drivers passing auxiliary signals when at danger. The ordinary rule with regard to danger signals was that a driver should be at liberty to come up to a danger signal but not to pass it without authority from the person in charge of it, except in the case of an auxiliary signal. As the person in charge of an auxiliary signal was generally at a distance of from a quarter to half a mile, it was necessary to allow a driver to pass it after having brought his train to a stand as

near to it as possible. If after having passed an auxiliary signal at danger a driver saw the home signal at all right, he would be allowed to proceed without stopping, as after passing the auxiliary he would take his directions from the home signal in front of him.

The real danger arose from the man in charge of signals looking on an auxiliary signal as a danger signal of an ordinary kind, and attempting to protect an obstruction with an auxiliary signal alone, while it is not an ordinary signal, but one which when at danger a driver is allowed to pass.

A main signal at each end of a station was most desirable, as no obstruction should ever be placed between the home signal and the auxiliary.

He most fully agreed with the remarks of Mr. Napier with regard to the necessity of enforcing discipline; every one acquainted with the working of railways knows perfectly that certain orders are constantly disobeyed. Numbers of accidents have happened from the line being occupied by a train shunting when a fast train, not stopping at the station, is due, although this is distinctly contrary to orders; constantly the press of traffic is considered a sufficient excuse for neglecting an order. Nothing in the management of railways was more required than strict discipline and great punctuality. Far greater punctuality than was usual in the very best worked lines was possible, and he believed it would be very much for the advantage of railways to enforce tbe greatest punctuality. One of the many advantages of the block system was that it facilitated the punctual working of trains.

The PRESIDENT agreed with the author that the punishment for negligence whereby an injury was caused, should fall on the persons guilty of the negligence, but thought the "*ad-misericordiam*" appeal for the shareholders was pushed too far, because as the injustice alluded to was thoroughly well

known at the time of purchase, the price paid for the shares must have been, to some extent, affected thereby, and if a reformation in the law could be effected to relieve the shareholders, the price of the shares would go up at once; there is, therefore, a slight mistake in extending too much compassion to the shareholders, at any rate to those who were not original subscribers; they are rather to be congratulated on having acquired property with a grievance attached, the removal of which is, at any rate possible, with immediate pecuniary advantage.

Public-road level crossings were, no doubt, objectionable, but cases occur where the cost of bridges and approaches would be out of all proportion to the convenience they would afford, having regard to the traffic on the roads; the General Act declares that a substituted road shall be provided for every one interfered with, and the road authorities, except by acquiescing in the clause of a special act for shutting up or diverting a road, seem to be powerless in the matter.

It is, perhaps, not sufficiently well known that no deviation or other alteration of a road is in the slightest degree authorized by its being shown on Parliamentary plans and sections, unless it is also specially set out in a clause in the Act.

As to private level crossings, the Act appears to be strained in saying that one gate must be shut before the other is opened; the wording certainly is "any gate," but the intention evidently is that a man shall not leave the railway without having closed what he has opened.

The danger arising from driving cattle across a railway may be greatly lessened by erecting dwarf walls or palings from the gate posts to within 4 feet of the rails, thus reducing the distance within which cattle may stray from some 50 or 60 feet to 14 feet.

The metropolitan system of placing the booking offices over the rails undoubtedly effects what is claimed for it; in fact, it

prevents a passenger from being on a wrong platform at any time; there is some difficulty, however, in applying it to our railways here, where we should have to make the summit of a road approach the cab-yard of a station.

If foot-bridges are put up at stations, their use should be rigidly enforced.

Distant signals, he thought, were always regarded as indicators of the state of the home signals, and in this view there is nothing inconsistent in running through them when at danger. If, of course, this idea is not present to the mind of the driver, and that he regards both as signals to stop, one of which *must* be obeyed, but the other may be neglected by custom, the position taken in the paper is incontrovertible.

The arrangement proposed amounts to abolishing the home signal, and working the distant as main signals. The difficulty appears to be that they must be either too far apart, or have each a distant signal beyond it. The latter would be no improvement on the present arrangement.

On railways in Germany the semaphore caution signal is not used at all. There is a caution signal there, but it is only given by hand—by day by a flag, *in its case*, being waved—at night by a green hand lamp.

The system of signals on the Köln-Minden line is as follows:—

At the points at the entrance to a station, at nearly every level crossing, and at the entrance of most tunnels and large cuttings there is a signal post, with box for a signalman, and a telegraphic apparatus worked from the signal station on either side.

On a passenger train coming into a station, or two minutes before a goods train leaves, the telegraph clerk signals to the next station, and the signal is set to "Leaving station." On arriving at a station, leave to enter is given at night by a green light, by day by the usual all-right signal, which is by

the arm being inclined *up*, at an angle of 45° with the vertical.

The points are all worked separately, and at each there is an indicating signal, which in the newest arrangement is a rectangular glass box, illuminated at night.

It will be heard with surprise that interlocking is absolutely unknown in this part of Germany. The signals and signalmen are so numerous that a driver is seldom out of sight of signals, which are met with on an average one in every half mile. On single lines there is no train-staff or train-porter arrangement known, nor any rule against sending on trains at very short intervals, the protection afforded being that of the rules for signalmen which require them to stop a train which, "in their opinion," is too close on the heels of the preceding one.

And yet this is a line which would here rank among the first. From Köln to Minden is 163 miles, the same distance q. p. as from Dublin to Cork; and of seven daily passenger trains each way, three do the journey in under 5 hours, namely, in 4 hours 30 minutes, 4 hours 50 minutes, and 4 hours 53 minutes, respectively.

One source of danger has not been touched on, on which it would be interesting to have some information, viz., colour-blindness. Has any accident been directly traced to the colour-blindness of an official, and what precautions are taken to guard against danger from this source?

Mr. J. C. Smith in reply, stated that he did not mean to advocate the abolition of distant signals, except a block system was introduced instead; theoretically at least, this accomplished for long lengths of line what the distant signals did (in a very inefficient manner, as proved by the Board of Trade report) for very short lengths; he maintained that when distant signals had to be used they should be of a construction different from that of the main signals, so as not to

confuse the driver, a thing which, to his knowledge, frequently occurred; he tried to meet this in an incomplete way, by making the end of the vanes fishtail for the distant, and square for the main signals; as to working the distant as a repeater of the main signal, it appeared to him to involve the possibility of a collision, by a train which had been standing between main and distant signals slowly advancing when the main was lowered being run into by a train coming up at speed beyond the distant signal, which would then be lowered as repeating the main one.

He agreed that there was a mechanical difficulty in working these signals by one wire, and did not see a better way of meeting it than having two vanes, with a wire to each.

Since reading the paper he had been shown Mr. W. H. Preece's pamphlet on Railway Electric Signalling, which prescribes the following rules for block system on single lines:—

1. No train or engine is to be allowed to pass your box unless the electric signal for the section into which it is about to proceed stands at "All clear," and the line has been blocked at the station in advance, thus:—

2. On the arrival of a train or engine at your box, you will, provided the electric signal stands at "All clear," at once signal to the next station in advance—"Train coming" (No. 9, Bell Code).

3. You will then place your switch handle at "On," thereby placing the electric signal at the station in advance at "Danger," and preventing another train from meeting that entering the section.

4. The station in advance will, before acknowledging the above signal, put on the danger signals—station and distant—against trains coming in the opposite direction to that from which the train is approaching his station, and keep such signals on till that train arrives, and the section is clear.

5. On receiving the acknowledgment to the above signal, the train may enter the section (No. 2, 3, or 4 Bell Code).

6. The arrival of the train at the station in advance will be signalled—Line clear—Train out (Bell Code, No. 10).

7. You will then remove the electric danger signal, and clear the line.

8. No signal is to be considered complete until it has been acknowledged.

NOTE.—These signals are not intended to alter or supersede the working arrangements already in use for altering the meeting places, but to prevent (as they will prevent), two trains on a single line meeting each other between any two stations.

It is hoped that Railway Managers may find the combined staff and telegraph arrangement recommended in the paper more simple and efficient than this plan; Railway servants will not, as a rule, always obey instructions to do things which they consider useless or unnecessary, but if they clearly understand the use of a simple method, such as the staff system, it will be attended to.

[27th May, 1874.]

CHARLES P. COTTON, President,
In the Chair.

The following Candidates were balloted for and duly elected:—

RICHARD F. KEANE, JOSEPH PHILIP RONAYNE, HORACE UNIACKE TOWNSEND, as Members; EDWARD M. BROWNE, JOSEPH POPE CULVERWELL, JOHN R. WIGHAM, as Associates.

On a NEW KIND *of* LOCKING GEAR *and* SAFETY FACING POINT. By J. BAILEY, Vice-President.

MANY and various are the forms of interlocking gear now in use on our great railway system, each vying, as it were, with the other in complication, till they seem to have culminated in a net-work of rods and cross-rods, bolts, locks, rocking and tumbling shafts, almost equal to a Chinese puzzle. A simple and good "lock," capable of being worked with any number of levers without adding to the complication, has long been wanted, and such a "lock" the author believes he has succeeded in making, and for the arrangement of which he has secured a patent. It consists of a number of flat bars (Plate XII., Figs. 3, 4) moving in a guide trough sitting on, and fixed to, brackets cast on the "lever frame," as at A in Figs. 1 and 2. These guide troughs and running bars are notched out to admit the horizontal bars B in Fig. 2 to rest in them. On the under side of the bars B is fixed an angle bar or incline plane (Fig. 5), which actuates the running "lock bar" when the lever, to which it is attached, is pulled over. It will be seen at once that by the movement of any one of these

"running bars," any or all the levers can be most effectually locked or released at will. Each lever in the "locking frame" is provided with a horizontal bar B and "lock rod," which is in no way connected to, or influenced by, the other levers or "lock bars"—in fact, each lever has power to "*lock*" or "*unlock*" all the others, and is in no way affected by them. The *lock* or *release* also takes place on the *slightest movement* of its lever, which of course is most desirable.

On referring to the plan, Fig. 3, it will be seen at once that No. 1 lever, in its normal position, is locked by No. 3, so that 3 releases 1, and 1 on being made *back* locks 3. In the same manner 2 is locked in its normal position by 4, and on 4 being made it not only releases 2, but at the same time locks 3, and 2 on being made *back* locks 4.

When it becomes necessary to use "facing points," it is found an improvement to "fix" or "lock" them immediately at the points as well as by the interlocking gear in the signal house. This "lock" should be so arranged as to prevent the possibility of the signalman shifting his "points" during the time a train is actually passing through them. Plate XIII. represents a "lock" of this description, also patented by the author. It consists of a pair of light tee or angle iron bars A A placed inside the running road, and immediately in front of the points L L. The far end of these bars is pivoted to the rails by steel or iron pins passing through both, and the near end is provided with cast or wrought iron wedges, so arranged as to override the points some two or three inches. The gauge is secured by means of the cross bars I I. B is a rocking shaft provided with cranks and short connecting rods J. E is the "points box," containing a cranked rod or incline plane F, which actuates the points by means of the rod H. The advantage of this arrangement is that one lever and one line of points rod is sufficient for working the "points" and "lock bars," in place

of two levers and two lines of points rods as in other arrangements. There is also another advantage, and of far greater importance, which is, that the points are not affected by the contraction and expansion of the line of gun-barrel points rod. Before shifting the "points" it is absolutely necessary that the tee or angle iron bars should be lifted high enough to allow the wedges to clear the top of the "switch rails," the switches are then shifted, and the "wedges" descend and so fix them in their proper position. The tee or angle iron bars are 16 to 18 feet in length, and are placed about two inches below the top of the rails, so that the flanges of the wheels of a passing train being immediately above them most effectually prevents the bars from lifting to release the wedges before the last pair of wheels of the last vehicle have passed the points.

On the Use *of* Peat *in* Steam Engines *and* Siemens' Furnaces. By Alexander M'Donnell, Vice-President.

Before entering on the more immediate subject of the present paper, it may be useful to remark generally on peat and the method of manufacturing it by machinery. The top of a bog is mostly a fibrous or mossy peat, varying very much in thickness, and only partly formed into true peat. This weighs from 30 to 50 lbs. a cubic foot when dug from the bog, which does not produce more than from 7 to 10 lbs. of dry peat. The weight of a cubic foot of this dry peat varies from 5 to 17 lbs., and in drying it contracts so that it occupies from 44 to 68 per cent. of the space it occupied when wet. This is a very inferior and worthless fuel. Under the mossy top peat there are three or four beds varying in their quality, but on an average a ton of the peat as taken from the bog

contains from 42 to 48 cubic feet, and it requires from 175 to 225 cubic feet to make a ton of air-dried peat. It may be roughly estimated that an acre of bog, four feet thick, will produce about 1,000 tons of air-dried turf.

A fair sample of cut turf weighs about 33 lbs. a cubic foot. This when packed close in a wagon will weigh 21 lbs. a cubic foot, and when put in loosely 17 lbs. a cubic foot. Black turf weighs from 40 to 44 lbs. a cubic foot, when well packed closely 33 lbs. a cubic foot, and when loose 23 lbs. a cubic foot. When pretty well dried a solid foot of turf will weigh about double what the same will weigh when loaded into a wagon. The quantity of water in wet peat, as cut from the bog, varies from 70 to 85 per cent., and this will give from 20 to 40 per cent. of air-dried turf, which will contain from 20 to 25 per cent. of water. An average sample of brown turf of good quality weighs, when wet, 46 to 50 lbs. a cubic foot, it contains 80 per cent. of water, 26 to 28 per cent. of air-dried turf, and 20 per cent. of dry fuel. A ton of such turf when wet will contain from 47 to 48 cubic feet, and it will require from 175 to 185 cubic feet to make a ton of air-dried turf. The densest mountain turf requires about 75 cubic feet or two and a-half tons of wet turf to make a ton of air-dried turf. An ordinary piece of turf cut from a bog does not contract in drying equally in all directions, the contraction in the vertical direction being greater than in the horizontal. Turf from different parts of a bog, and from different bogs, varies very much in this respect, but generally the roots and fibre being in rather horizontal layers prevent the shrinkage. When peat is reduced to pulp, the fibre being more or less broken up, the contraction is equal in all directions, and is rather greater than the greatest contraction of the cut turf. Peat reduced to pulp and moulded by machinery has also a smoother surface, packs closer, and throws off wet better than cut turf. It also seems to have an advantage in drying

faster, particularly during the first few days. The amount of advantage in drying arising from the fibre being broken up does not seem to be very accurately known, but probably it is not as great as some seem to suppose. If samples were made of equal size and put in similar positions, there would be no great difference in the time necessary for drying, although for the first few days the machine-made peat would have the advantage. The author has not himself made sufficiently careful experiments on this to arrive at a very satisfactory conclusion. In order to find the exact amounts that peat contracts when cut in the ordinary way and when reduced to pulp, samples were cut to exact dimensions, and samples of the same were pulped and moulded. They were carefully measured when wet, and afterwards when well air-dried. The following table gives the amount of contraction from drying and the weight of a cubic foot of the dry turf:—

		Contraction per cent. of original size	Weight per cubic foot when air-dried
Sample from top of bog, - -	cut	27·73	39 lbs.
" " " - -	pulped	21·19	58 "
Sample from middle of bog, -	cut	35·18	30 "
" " " - -	pulped	19·71	50½ "
Sample from bottom of bog, -	cut	31·13	32 "
" " " -	pulped	20·49	55 "
Sample of black brittle turf, -	cut	40·56	30 "
" " " - -	pulped	25·75	47 "
Sample of top moss turf, - -	cut	57·75	7¾ "
" " " - -	pulped	59·00	16½ "

From this it may be inferred that peat when pulped and dried contracts to about one-fifth of its original size, and when

cut in the ordinary way and dried it contracts to rather less than a-third of its original size. This is when the peat is of good quality and extremely well air-dried. The samples which were pulped were afterwards dried with artificial heat, and lost from 12 to 17 per cent. more moisture. They were then allowed to remain in water for about two hours when they absorbed extremely little moisture, but the brittle peat burst to pieces.

There are many machines proposed for reducing peat to pulp, and moulding it, and many will be found to work well. Different kinds of peat, however, will not be equally well worked by the same machine. The author would not adopt for ordinary peat of good quality any of the machines which are said to cut the peat. A certain amount of cutting is probably necessary with some kinds of peat, particularly when it contains many roots and sticks, but, as a general rule, peat which is worth working by machinery is easily reduced to pulp, the fibre being rotten and easily broken up. Peat in which the fibre is not rotten is extremely difficult to cut, and is hardly ever worth working by machinery as it will not give a dense fuel by any manipulation. A bog of fibrous peat generally contains a quantity of what the people on the bog call "horse flesh," which it is nearly impossible to cut. It is very likely to break the knives or choke any machine which attempts to cut it, unless the machine is what might be considered uselessly strong and expensive. The bog from which the author has made peat being extremely bad and full of fibre, he has adopted a machine which does not cut the peat, but reduces it to pulp by blows; it is not, perhaps, better than many other machines, but it is a simple, strong, and cheap machine (Plate XIV.). There is a horizontal casing A, the bottom of which is a semi-cylinder, the sides being vertical—something of the form of the letter U. In this a horizontal shaft B works with a number of blades C at right angles to it, each

blade having a slight twist, so that the peat thrown in at one end is thrown out at the other. This part of the machine is exactly similar to the concrete-mixing machine adopted by Mr. Stoney (see Plate VIII.). The peat thrown in at one end is reduced to pulp by the rapid blows of the blades, and is delivered at the other end into two cast-iron cylinders D in which two screws work. These screws press the pulped peat out through four mouthpieces in four continuous streams. It is received on wooden trays E which are pushed forward on rollers by the peat itself as it is forced out. When the tray is full the peat is cut into lengths by hand; the tray is taken away and another pushed up to take its place. The trays are placed on small wagons constructed to carry them, with small spaces between, so as to allow the air to circulate. After about two days the peat is sufficiently dry to be turned off the trays on to the ground or the floor of the shed. In a few days they are turned and afterwards piled so as to make room for more. The peat as it comes from the machine is rather larger than the section of the mouthpieces, which is $3''\frac{1}{2} \times 2''\frac{2}{3}$. Each tray takes the peat from two mouthpieces, the length being 28 inches. Each wagon holds 240 trays, and on an average it takes 42 minutes to make a wagon full.

The bog on which the author has made trials is of a very inferior quality, the peat has to be raised a considerable height to put it into the machine, and there is not a sufficient space for drying the peat after coming from the machine; he cannot give, therefore, very accurately the cost of making a ton of peat from a good bog when the machinery is fixed in the most convenient way. Each tray holds the third of a cubic foot of pulped peat, and each wagon about 80 cubic feet. A cubic foot weighs 63 lbs., which is 12 lbs. more than the weight of a cubic foot of the peat as taken from the bog. A wagon made from peat six feet below the surface of the bog on which trials have been made, produces 8 cwt., but if made

from a good bog would produce from 9 to 10 cwts. If made from first-rate peat it would produce 12 cwts. or more. The cost of making a wagon is 3s. 2d., including drying and loading into wagons. The cost of making a ton of dry peat will, therefore, vary from 7s. 11d. to 6s. 4d. according to whether 8 or 10 cwts. are produced from a wagon of wet pulped peat. Probably the cost of making a wagon of pulped peat might be reduced to 2s. 10d., or perhaps less. In this case the cost of a ton of dry peat would vary from 7s. 1d. to 5s. 8d. according to the quality of the bog. It will be seen from this how much depends on the bog being of good quality, so that in order to get a ton of dry peat as small a quantity as possible of wet peat should be required.

Before going into the manufacture of peat on anything like a large scale, it is, of course, necessary to obtain some reliable information as to its value for commercial purposes as compared with coal. In many places for domestic use peat and coal do not come into competition at all. The only question being how peat can be made at the lowest price, and as far as possible independent of the weather. There are other places where they do come into competition, but it would be an extremely difficult thing to give any idea of the comparative value of the two fuels. The fact is, that for domestic purposes all fuel is used in a most wasteful and extravagant way, so that it is impossible to give any true value to any fuel.

The author has tried peat against coal in a boiler for a stationary engine, in a locomotive, and in Siemens' Regenerative Gas Furnace. In a stationary boiler of the locomotive form 36½ cwts. of peat (common air-dried) kept up steam for a day, the average consumption of Welsh coal being 17½ cwts. The coal had a good deal of small, and was not quite equal to average coal. This gave 100 tons of peat as equivalent to 48 tons of coal.

In a stationary boiler of a similar kind 120¾ cwts. of peat

kept up steam for two days, the consumption of Welsh coal for the same time being 59½ cwts. This gave 100 tons of peat as equivalent to 49·3 tons of coal.

A locomotive ran 347 miles with a light goods train, with 11 tons 9 cwt. of peat, or 73·9 lbs. a mile. The same engine ran the same distance with a rather heavier train with 5 tons 12 cwt. of Welsh coal, or 36·1 lbs. a mile. This gave 100 tons of peat as equivalent to 49 tons of coal. In this trial the train with which the peat was used was lighter than the train with which coal was used, and the consumption of coal was greater than the average. The consumption of coal with the train with which peat was used would not have been more than 32 or 33 lbs. a mile, which would give a proportion of 100 tons of peat as equivalent to 43 tons of coal.

A locomotive ran 520 miles with a passenger train, the average load was 7·6 six-wheeled carriages, the maximum load 14 carriages, the speed 29 miles an hour. The consumption was 12 tons of peat, or 51·6 lbs. a mile. The same engine ran 663 miles with a passenger train, the average load 6·4 carriages, the speed 30 miles an hour. The consumption was 6 tons of Welsh coal, or 20·3 lbs. a mile. This gives 100 tons of peat as eqiuvalent to 39 tons of coal. In this trial the consumption of coal was rather low, and the train with which coal was used lighter than that with which peat was used. The average consumption of coal with the same engine for the previous month was 21·6 lbs. a mile, which would give 100 tons of peat as equivalent to 42 tons of coal.

Another trial with a locomotive with a passenger train gave the following result. Distance run 694 miles, speed 29 miles per hour. Average load 7·1 carriages; consumption 15 tons 3 cwts. of peat, equal to 48·9 lbs. a mile. The average consumption of coal with the same train was from 22 to 23 lbs. a mile, which would give 100 tons of peat, equivalent to from 45 to 47 tons of coal.

The total result of these trials would give 100 tons of peat, as equivalent to from 48 to 49 tons of coal, when used in stationary boilers, and as equivalent to from 40 to 47 tons of coal when used in locomotives. The price of coal being taken at 20s. a ton, the price of peat should be from 9s. 6d. to 10s. a ton in order to compete with coal in stationary engines, and from 8s. to 8s. 6d. a ton to compete with coal in locomotives.

The most favourable results in the use of peat which the author has obtained is from Siemens' Regenerative Gas Furnace for heating iron for large forgings, under a steam hammer. In the Regenerative Gas Furnace, the principles of which are so well known as to require little explanation, the fuel is converted into gas in a producer, which is a rectangular brick chamber, with one side inclined, and a grate at the bottom. The fuel is charged through a box or hopper, and falls in a thick mass on the grate. Air is admitted at the grate, and first forms carbonic acid with the carbon of the fuel, which, rising through the ignited mass, takes up another equivalent of carbon and forms carbonic oxide. The hydrocarbons and the moisture are distilled by the heat, and the carbonic oxide mixed with these, and diluted with nitrogen, rises to the top of the chamber and is carried off through a tube to the furnace. In passing through the tube the gases are cooled and the moisture and tar are condensed.

The furnace is built with four chambers underneath, which are filled with fire-brick, stacked loosely with spaces between. The gases passing through the cooling tube from the producer enter the furnace through one of these chambers, the air necessary for combustion passing through the one next it. The air and gas meet on entering the furnace and enter into combination. The combined gases with the waste heat of combustion pass away to the chimney through the other two chambers, giving up a large quantity of heat to the brick-

work. After a time (generally about half-an-hour), a properly arranged system of valves are turned, and the cold air and gas enter through the two heated chambers, becoming heated by passing through the brickwork. The gases with the waste heat pass away to the flue through the chamber through which the gas and air formerly entered. By thus reversing the current regularly, almost all the heat of combustion is retained in the furnace, and an extremely high heat is obtained.

It will be seen at once that the disadvantages of peat as a fuel—its bulk, its dampness, and its not being able to withstand a blast—do not prevent its being used with advantage in such a furnace. The moisture of the peat must, of course, be driven off, but this is done in an inexpensive way, and when the cooling tube is sufficiently long, the vapour is condensed, so that it does not injure the inflammable gases.

The water which is in the peat in the form of moisture is not, in the author's opinion, decomposed, as it is distilled off at too low a temperature. There is a slight loss of heat in vapourizing the moisture, and again in cooling the gas so as to condense the vapour. The loss is, however, slight, as there is hardly anything gained by allowing the gas to enter the regenerative chambers at a high temperature, because the temperature of the waste gases as they pass away to the flue must be at least as great as the temperature of the gases entering the regenerative chamber. The condensed water and tar run in a constant stream from one end of the cooling tube.

Before the Siemens' Gas Furnace was erected the author used an ordinary air furnace for heating iron for large forgings under a steam hammer. Taking the average from half a year's working, it required 4·96 tons of Ruabon coal for a ton of finished forgings, using this air furnace. The result of ten weeks' use of peat in Siemens' Gas Furnace gave 5·09 tons of peat to a ton of finished forgings. The result of six weeks use of coal in Siemens' Gas Furnace gave 3·6 tons of coal to

a ton of finished forgings, and the result of the last three of the six weeks, which, probably, is the most correct, gave 2·86 tons of coal to a ton of finished forgings. This gives 100 tons of peat as equivalent to 57·2 tons of coal.

Supposing that coal of sufficiently good quality to be used in a gas furnace, can be got for 5s. a ton less than the best coal, so that when the price of the best coal is 20s. a ton, the price of the inferior coal is 15s. a ton, then the price of peat should be 8s. 6d. a ton in order to compete with such coal in a Regenerative Gas Furnace.

The successful use of peat in this furnace has been greatly due to the intelligence and care of the men employed at it. The author's foreman, Mr. Owens, who had never worked, and had only once seen a furnace of the kind, has had entire charge of the working of the furnace, and its success has been greatly due to his intelligence and perseverance. Everyone knows how difficult it sometimes is to introduce anything new, and there have been great difficulties found in introducing Siemens' Furnace in some places, but from the time this furnace was first lit it has worked in a satisfactory way.

In order to test how soon after been cut from a bog peat could be used in the gas furnace, some bog was cut and made on the 1st April, and on the 29th April it was used in the furnace.

The author exhibited to the meeting two outside coupling rods forged by this peat, also pieces of iron cut from the same forgings, and forged and bent cold so as to show the quality of the iron; also some pieces of steel melted in the furnace from old files, to show the heat which can be obtained from peat

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THIRTY-EIGHTH YEAR, 1874.

REPORT OF COUNCIL.

Since the last Report the following Papers have been read before the Institution:—

March 12th, 1873.—Remarks on Town Scavenging. By J. Lees Rosborough.

Dec. 10th, 1873.—Description of the New Syphons at the Wexford South Reclamation. By W. G. Strype, Member.

" " On the Discharge of Tidal Sluices. By C. P. Cotton, President.

The following new Members have been added:—

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The Donations of Books will be published in the Catalogue of the Library, now in preparation.

The resolution of the General Meeting of 21st November, 1873, has been carried out, and the rooms in Stephen's-green are now open; a copy of the rules for their regulation is appended to this Report.

It is not proposed at present to alter the arrangement for holding the evening meetings in Trinity College.

The Council hope that the accommodation and advantages afforded by this change will be such as to induce those belonging to the profession in this country, who are properly qualified, to become Members; and also that the number of Associates will be largely increased from amongst the younger Engineers, and those whose pursuits are more or less allied with Civil Engineering.

Several Members holding high positions in the profession having retired from the Institution some years ago, the Council recommend that up to the end of this year former Members may be allowed to rejoin without entrance fee and without ballot, provided a resolution for the re-admission of each be proposed by the Council, and passed at a General Meeting of the Institution.

The Council propose, in future, to send out their Report accompanied by the balloting list, in time for consideration at the December meeting of each year.

The tenth volume of Transactions is now in preparation, and a priced list of back volumes will be circulated amongst the Members to enable those who desire it to complete their sets.

A glance through these volumes will show that a large number of subjects of great interest to the profession in this country have

not been touched upon in any of the papers; many other matters, clearly illustrated by papers at the time, have so much developed and altered, that further information is very desirable; and the Council trust that the Members will afford to the Institution and the profession the results of their experience by means of these papers; and they may be assured that no record of careful observations of the progress of any work, whether the result be successful or not, can fail to be of interest and value.

RULES FOR THE REGULATION OF ROOMS.

Rooms to be open every week-day, excepting Good Friday and Christmas Day, from 9 a.m. to 5 p.m. Members and Associates to have free use of the rooms during these hours, and to be empowered to introduce visitors, upon entering their names in the book provided for the purpose.

No book or paper is to be removed from the rooms without a special authority from the Council, and it is requested that every book will be restored to its place on the shelves, and not left lying about.

Letters and messages for Members and Associates, addressed to 136, Stephen's-green, West, Dublin, will be taken charge of by the attendant of the Institution.

Writing materials are provided, and it is requested that any suggestions for the greater convenience of the Members may be entered in the Observation Book, which will be laid before every Council.

The Treasurer's Account, up to January 1st, 1874, duly audited, is as follows:—

INSTITUTION OF CIVIL ENGINEERS IN ACCOUNT WITH ITS TREASURER.

Dr. *From JANUARY 1st, 1873, to JANUARY 1st, 1874.* Cr.

	£	s.	d.					£	s.	d.
To Paid Assistant's Salary, one year, .	24	0	0	By Balance in Treasurer's hands 1st January, 1873, . .				85	16	11
,, Payments to Attendants, and Refreshments at Evening Meetings, .	10	8	6	,, Cash Received, viz.:—						
,, Postage and Incidental Expenses, .	4	4	6	Subscriptions,	£65	2	0			
,, Falconer, for Printing, &c., &c., .	22	16	3	Entrance Fees, . .	8	18	6			
,, Advertising, ...	0	18	0	Life Composition, .	23	12	6	97	13	0
,, Balance in Treasurer's hands, . .	128	19	2	,, Dividends on £264 12s. 6d. new 3 per cent. Stock, ...				7	16	6
	191	6	5					191	6	5

We have examined the above Account, and certify it to be correct, leaving a Balance in favour of the Institution of One Hundred and Twenty-eight Pounds Nineteen Shillings and Two-pence.

BINDON B. STONEY, } *Auditors.*

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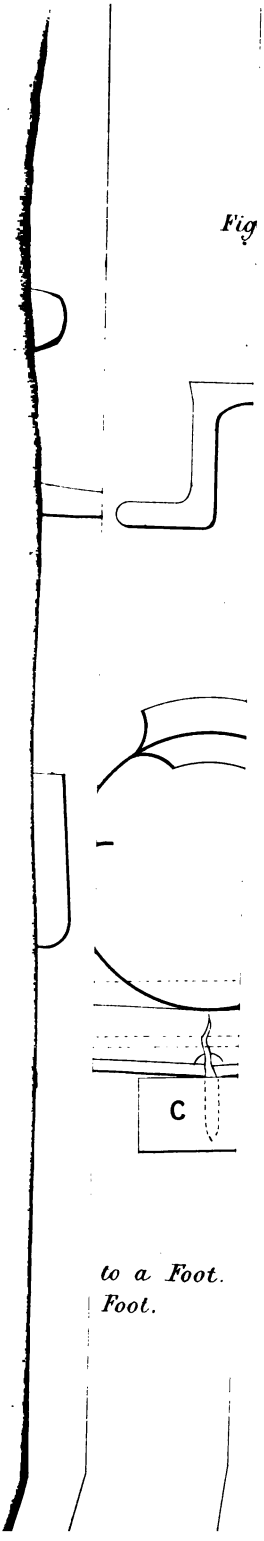

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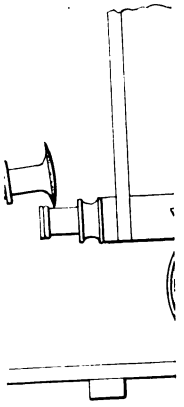

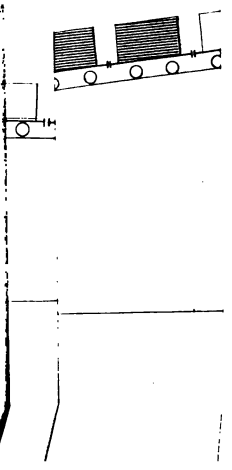

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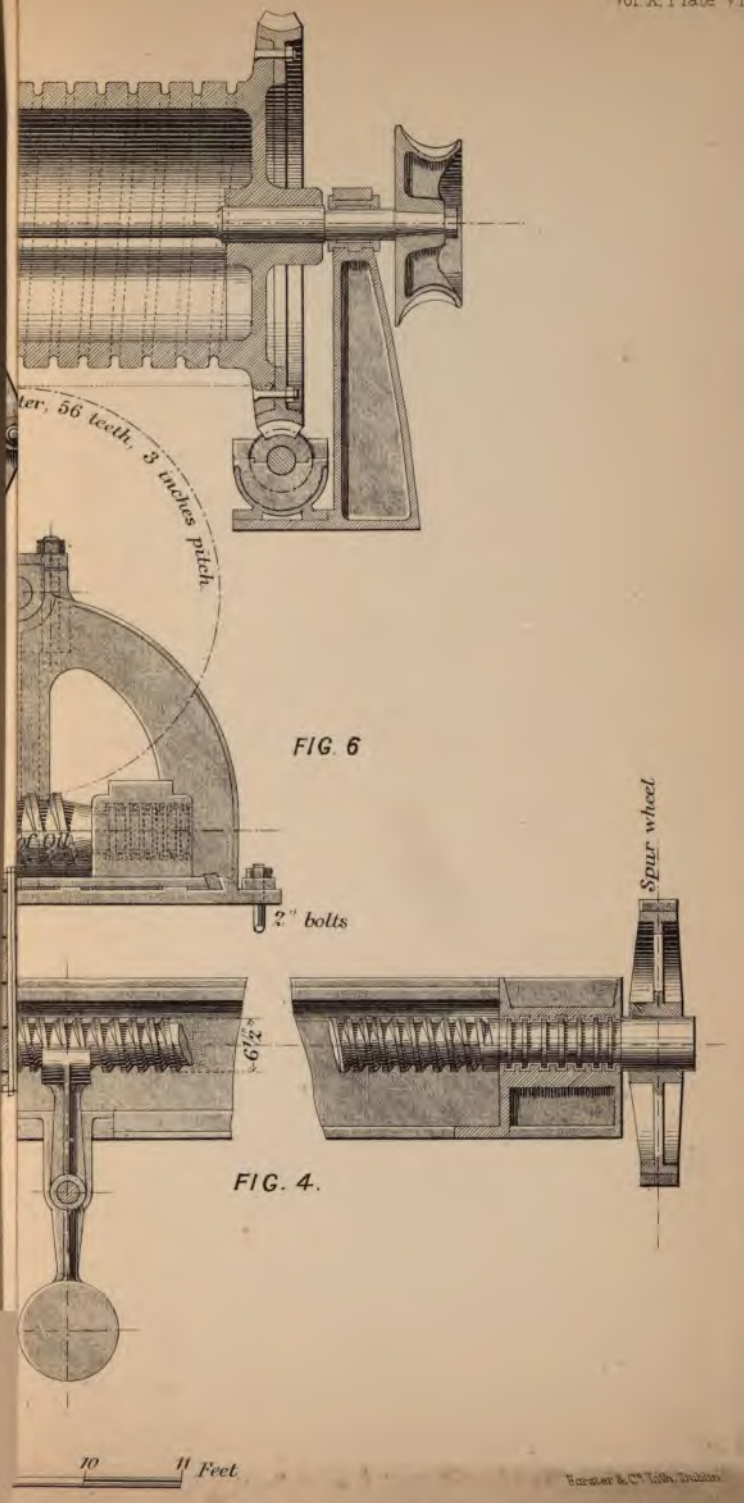

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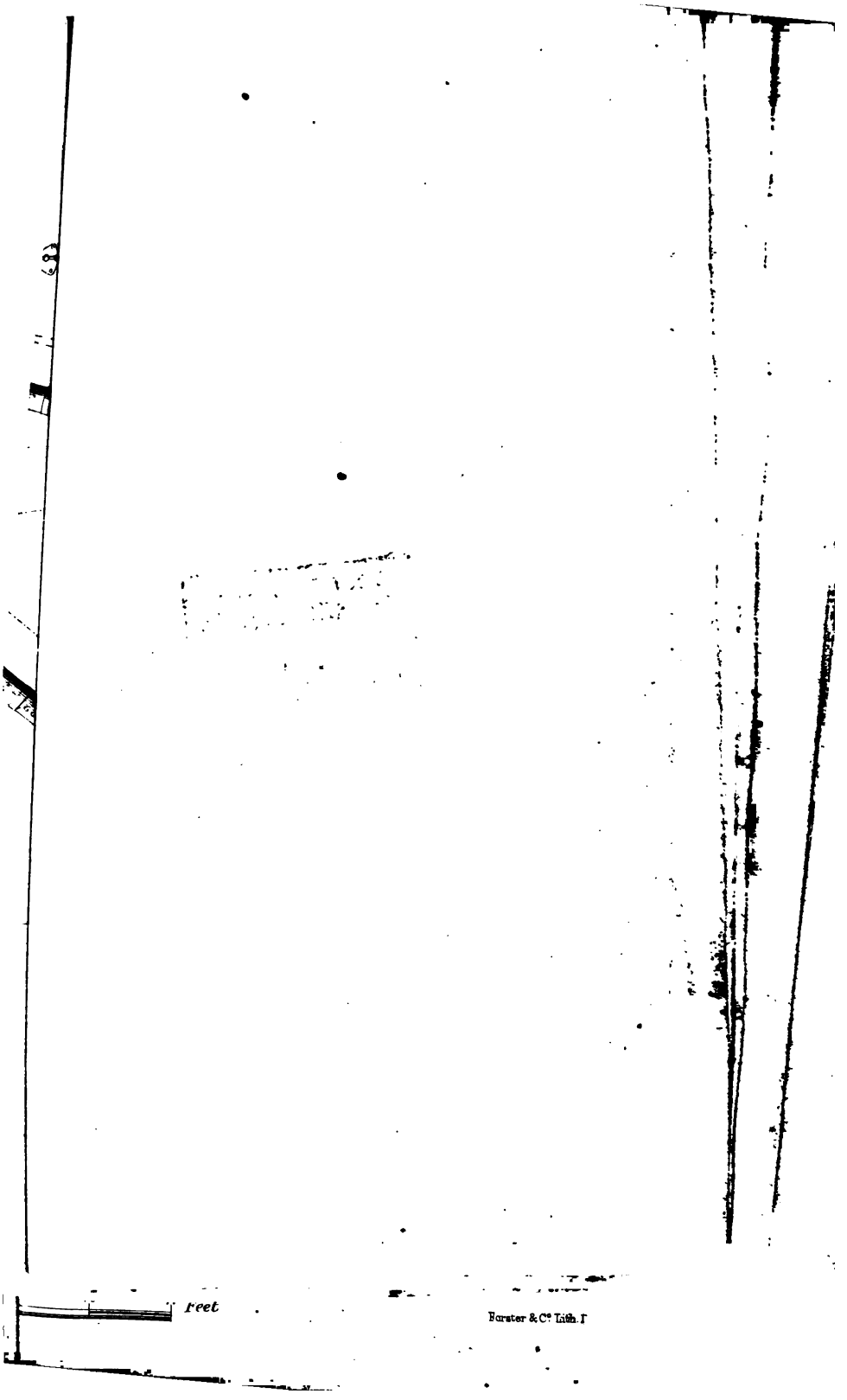
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Fig. 2.

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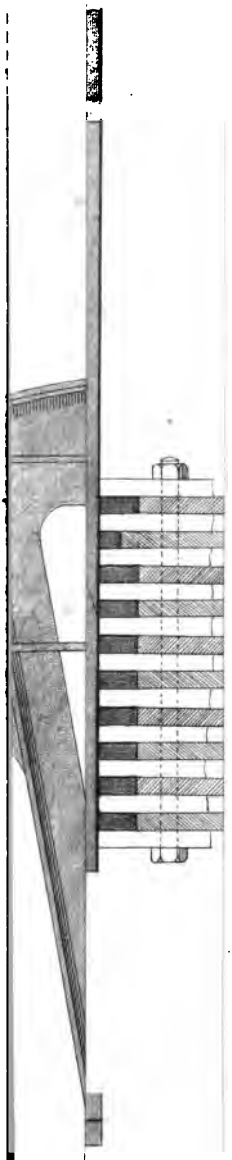

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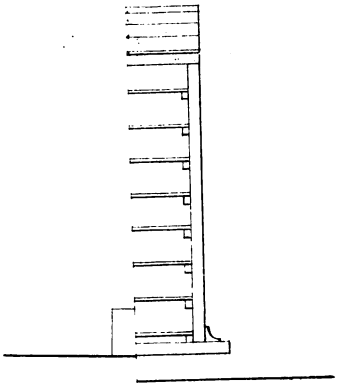

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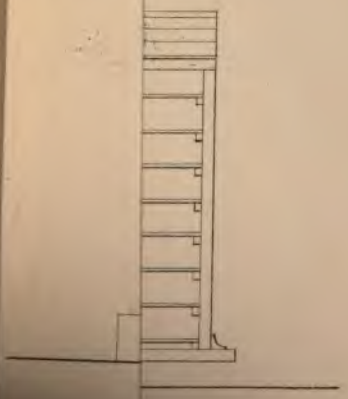

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